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ENACTING RICH MATHEMATICAL TEACHING AND LEARNING TO MOTIVATE PUPILS TO ENGAGE: AN ACTION RESEARCH STUDY

By

Clare Kealy

A Research Dissertation

Submitted to the Froebel Department of Primary and Early Childhood Education, Maynooth University, in fulfilment of the requirements for the degree of Master of Education (Research in Practice)

Froebel Department of Primary and Early Childhood Education

Maynooth University School of Education,

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September 2020

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Dedication

This dissertation is dedicated to my family and friends, especially my mam and dad, Jim and Catherine Kealy. They gave me the motivation, intelligence, and desire to complete my degrees and the determination to continue to learn more each day. Without their support, encouragement, and wonderful proofreading skills, I would not have been able to complete this journey. Thank you for keeping me in the master program by believing in me. I am blessed beyond measure to have such a wonderful and caring family and many friends to support me in this endeavour.

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Abstract

Utilizing action research as the methodology, this study was developed with the ultimate goal of enhancing pupil motivation and engagement in mathematics by enacting rich mathematical teaching and learning, which involved a move away from the didactic style of teaching and towards a more student-centred teaching approach. The research question that guided my work was as follows:

How does enacting rich mathematical teaching and learning affect pupil motivation to engage in mathematics lessons?

Several theories inform this study including the work of Dewey, Freire, and Chomsky, as well as Lortie's idea of the Apprenticeship of Observation and Whitehead's theory of experiencing oneself as a living contradiction. Theories relative to the themes which emerged from the coding of the data are explored, as is theory relating to that of the Action Research Paradigm.

Both qualitative and quantitative data collection methods were used and these methods of data collection were utilized in order to show a change in my teaching and to enable me to show that my teaching is now more in line with the values I hold. They also enabled me to monitor the level of engagement and motivation from the children.

The research revealed the following salient findings that enacting a student-centred approach to teaching as opposed to a didactic style of teaching can increase pupils' engagement levels, as well as their motivation and can help to develop the children's critical thinking skills.

Additionally, change was gradual and difficult due to the complexities of teaching. However, I feel that by being both a teacher and a researcher who is conducting research in my own classroom, and thus encountering these complexities, can therefore help to bridge the gap between research and classroom practice.

Chapter One: Introduction

The ultimate goal of this dissertation is to enhance pupil motivation in mathematics in order to increase pupil engagement. Enhanced motivation was enabled by enacting rich mathematical teaching and learning. More specifically, assuming an action research paradigm, this study involved the design, implementation and study of my teaching of mathematics in the classroom and how I can change and improve my teaching of the subject in order to motivate pupils to engage more with mathematics. This study intends to investigate pupils' motivation to engage with mathematics by enabling me to move away from a didactic style of teaching and towards a more student-centred teaching approach. This research study consists of two cycles of an adaptation of a basic action research model, adapted from that of Kurt Lewin's (1946), Kemmis and McTaggart's Model (1988), and Whitehead and McNiff's (2006) action research model and it consists of a four step cyclical approach to action research involving reflecting, planning, acting, and observing.

This first chapter presents an overview and introduction to the study. It begins by identifying the problem that the study attempts to address, followed by the goals of the study, and why action research was chosen as the methodological approach. A brief overview of the design of the study is then discussed, followed by a first articulation of the research question that guided the data collection and analysis. The main data sources are also identified and the chapter concludes with an overview of the key findings and significance of the study to the field.

A review of the literature that informed this study is then provided in Chapter Two. Detailed description of the various steps involved in the action research cycle can be found in Chapter Three. The findings of the research are presented in Chapter Four,

while Chapter Five describes the implications of these findings, with respect to actions and practices, before summarising the highlights of the study, along with its limitations and contributions.

Identification of the Problem and Goals of the Study

I would strongly agree with the quote, "when teachers support students to deeply engage with concepts and practices, students make sense of mathematical ideas, engage in mathematical practices, and make connections across ideas" (TeachingWorks Resource Library, 2020). However, this was not evident in my classroom prior to undertaking this study. In fact, on reflection on my teaching I realised that I was, as Whitehead (2006) describes, experiencing myself as a living contradiction. In other words, I held specific values but was not living up to these values in my everyday teaching. I value education, specifically student-centred education, and its ability to develop critical thinkers. I also place huge importance on the value of inclusion. However, when I reflected on my practice, I was actually enacting teacher-centred learning or traditional teaching and was developing passive pupils who received knowledge rather than constructed it. Nagashibaevna (2019) describes passive learners as pupils who take in new information and knowledge quietly and do not engage with this information. This was typical of the students in my classroom as I delivered the content to them. The pupils relied on information transmission from me, the teacher, with little evidence of interaction between us. The traditional teaching style considers students to be empty vessels who are expected to absorb the information, instead of discovering and constructing it and there is also a heavy reliance on textbooks. These traits were also evident in my classroom as I discuss in my reflective journal about one incident where a child groaned when asked to take out his workbook and said, '*Why do we always do work in our book, why*

can't maths be fun?' (Kealy, 2020). On another day, I described the sad look on '*their little faces'* (Kealy, 2020) as they were asked to take out their workbooks again.

This year, I started a new teaching job in a rural, co-educational primary school, where I teach junior infants, senior infants, and first class. I was also appointed Deputy Principal in September of this year, stepping up to Acting Principal in October. Since then, I have found myself trying to navigate the challenges which present themselves in this situation; adapting to a new setting, teaching three classes where there are two very different curriculums in place, as well as different books and resources being used, in addition to taking on the role of acting principal.

I had great cause for concern when I realised that the children in my classroom were not very motivated when it came to participating and engaging in mathematics lessons. This concerned me because the children I teach are quite young, with research suggesting that attitudes are adopted in these early years of one's life and those attitudes 'do not change easily except when one has importance experiences' (Arslan, Yavuz & Deringol-Karatas, 2014:558) Therefore, creating a positive attitude towards mathematics in the early years of primary school is absolutely crucial. It was on reflection of my teaching that I noted that I was not enabling pupils to develop this positive attitude towards mathematics due to the learning experiences I was providing them with. Thus, a lot of the tasks I was setting involved the children receiving knowledge rather than constructing it. This is where the important experiences, as mentioned by Arslan, Yavuz & Deringol-Karatas (2014), come into play, as the attitude a child forms towards a subject, be it positive or negative, is a direct result of the learning experiences they are exposed to, as well as their understanding of that subject as 'loving something requires understanding it. We

love nothing but the things we understand' (Arslan, Yavuz & Deringol-Karatas, 2014:557). I was enabling the lack of motivation by providing the children with learning experiences that did not aid the construction of knowledge in an inquiry-based approach but rather centred on children receiving knowledge rather than constructing it for themselves.

I feel the reason I was using a didactic style of teaching, whereby the children completed a lot of work in their textbooks, was because I found it hard at the beginning to balance my time between the roles of a mainstream class teacher, where I am teaching three classes, and that of an Acting Principal. As a result, I went back to what Lortie (1975) describes as the 'Apprenticeship of Observation' whereby teachers 'revert to their default model [which] can lead to teachers teaching as they were taught' (Borg, 2004: 275).

The context also had another major part to play, as we do not operate a book rental scheme in our school and, thus, I felt under pressure from parents to complete workbooks because parents had paid out for these books and would expect them to be completed.

Therefore, by studying my own teaching and utilizing the action research methodology, my goal was to make observations, analyse these observations, and record the changes made to my teaching that ultimately lead to an increase in the pupils' motivation to engage.

Theoretical Frameworks of the Research Study

Several theorists inform this study, as outlined briefly below. These are detailed more in Chapter Two: The work of Dewey, Freire and Chomsky where their view on education is discussed. Freire, Dewey and Chomsky were all critical of the didactic

approach to education. Freire (1970) disagreed with this style of teaching because he viewed education as the act of knowing and he felt that each child should play an active role in their own learning. Dewey (1990) also disliked this approach because he too was of the belief that education should be an active and inquiry-based process whereby children construct meaning and knowledge. Chomsky (2004) was critical of the didactic approach because he believed it hinders the development of critical thinking in children and prevents a child from understanding. Lortie's idea of the Apprenticeship of Observation is then discussed, as well as Whitehead's theory of experiencing oneself as a living contradiction. Lastly, theories relating to the three themes which emerged from the coding of the data (student-centred teaching, engagement, and motivation) are explored.

Action Research as the Chosen Methodology

'Self-study action research is a deeply values-based approach to critical reflection on one's own work. It is basically about you studying you… with a view to becoming a better practitioner' (Sullivan, 2016: 28). The reason I have chosen this methodology is because, as Sullivan discusses, it is based on one's own values and how I can improve my practice by examining these values in relation to my practice. Right now, I am not living as close to my values as I would like and, therefore, I feel a change in my practice is needed. The cyclical structure of action research allowed me to make these changes by engaging in a continuous process of analysing, reflecting and refining my own practice. Indeed, as Anderson, Herr and Nihlen (2007) describe, 'action research is sometimes described as an ongoing series of cycles that involve moments of planning actions, acting, observing the effects, and reflecting on one's observations. These cycles form a spiral that results in refinements of research questions, resolution of problems, and transformations in the perspectives of

researchers and participants' (p.3). This study involved two cycles of action research which will be discussed in depth in chapter three.

Overview of the Research Question

As noted, the purpose of this study is to increase pupils' motivation to engage in mathematics. One underlying research question will serve to guide this effort. The question is:

How does enacting rich mathematical teaching and learning affect pupil motivation to engage in mathematics lessons?

I explored this by focusing on the following more specific sub-questions:

1. How can I enact rich mathematical learning?
2. How can I increase pupil motivation to engage in mathematics?
3. How can I move away from a traditional style of teaching?

To address these questions, I designed, implemented, and studied a teaching and learning experience that focused on a more student-centred style of teaching. I moved away from the traditional style of teaching, which I have previously discussed, and instead enacted rich mathematical learning by implementing a range of engaging mathematical activities whereby pupils were involved in collaborative, inquiry-based learning, which enabled them to become critical thinkers and to construct their own knowledge.

Design of Intervention

With the goal of enhancing pupils' motivation to engage in mathematics, I first designed an intervention which would see me move away from a traditional style of teaching and instead enact rich mathematical learning by moving to a more student-

centred teaching approach. The student-centred approach enables rich mathematical learning, as it positions pupils at the center of inquiry and, thus, pupils are active agents in the learning process as they engage in constructing their own knowledge. Talbert, Hofkens and Wang (2018) discuss student-centred learning as the way in which pupils construct understanding of mathematical concepts by engaging in discussion, problem solving, comparing strategies, and through in-depth analysis of mathematical ideas. The authors' study discusses how, when pupils engage in these processes, they are deeply engaged in learning and thus rich mathematical learning takes place. They also discuss the strong relationship between student-centred instruction and how this approach increases pupil engagement in mathematics beyond that of traditional teacher-centred teaching. The intervention took place over seven weeks and was mainly conducted with the nine pupils in my first class; however, some data was also taken from the other twelve pupils in junior and senior infants. In the spirit of action research, participant feedback and actions, observations, and reflections informed the necessary refinements. Two revolutions of the action research cycle were completed.

Preview of Key Findings and Contributions of the Study

A range of data was collected during the intervention period in order to address the research questions informing the study. The study also generated additional and unexpected insights about other key elements that can contribute to pupils' motivation to engage in mathematics. The findings of this research also contributed to personal knowledge on how I can improve my teaching of mathematics in order to ensure pupils are engaged and to ensure the children's ability to think critically is developed. Former education minister, Mary Coughlan, previously discussed the importance of enabling students to develop the ability to think critically as she

addressed those in attendance at the Annual Congress of the Teachers' Union of Ireland (TUI) in April of 2010. The then Tanaiste indicated that she believed a change in focus was needed within the country's education system, which would see a move away from 'teacher-led instruction and the memorising of information and towards enabling students to acquire the key skill sets that enable them to be flexible and independent learners throughout the whole of their lives', suggesting that a stronger emphasis on critical thinking could be the answer. The primary school curriculum also highlights the importance of developing children's ability to become critical thinkers as it discusses how 'the ability to think critically, to apply learning and to develop flexibility and creativity are also important factors in the success of the child's life' (Department of Education and Skills, 1999: 7). It states that a 'strong emphasis is placed on developing the ability to question, to analyse, to investigate, to think critically, to solve problems, and to interact effectively with others' (Department of Education and Skills, 1999: 11). Thus, one of the main specific aims of the primary school curriculum is 'to enable children to come to an understanding of the world through the acquisition of knowledge, concepts, skills and attitudes and the ability to think critically' (Department of Education and Skills, 1999: 34).

While most of the insights I gained from conducting this research are consistent with the literature in the field of mathematics education, they were new learnings for me in my role as a primary school teacher. This will affect my future practice as I strive to carry this important learning experience with me throughout my teaching career. I also believe that, by disseminating the knowledge I have gained from this study, I can help other teachers to benefit from these insights.

Chapter Two: Literature Review

Introduction:

This chapter provides a review of the literature related to this study. My research question and problem are situated within the constructivist paradigm. This chapter consists of different sections. The first section outlines theories relating to the direct teaching approach. The second section contains a review of the literature detailing the student centred approach, while the third section is based on the idea of core practices. Relevant literature around inclusion, engagement and finally motivation is then discussed. Where I feel it necessary to link the relevant literature to my own experience and opinions, I will discuss this under the heading of reflection.

Traditional Teaching

Dewey (1990) and Freire (1970) are two prominent and influential figures in their respective fields and there are important similarities between them in terms of education. Both were critical of the traditional approach to education that I was implementing in my classroom. The traditional or didactic style of teaching refers to 'the traditional image of the students facing the teacher who is at the top of the class and who does most of the talking' (McCoy, Smyth and Banks, 2012). Freire referred to this as the 'banking approach', whereby pupils were considered to be empty vessels that require the teacher to fill them with information. Freire (1970) disagreed with this style of teaching because he viewed education as the act of knowing and as a process of enquiry. He believed that each child should play an active role in their own learning and that the didactic, teacher centred approach whereby pupils received knowledge rather than created it was a form of oppression of these children. He also valued the social aspect to creating knowledge, as he noted that mutual, respectful dialogue has the capacity to create new knowledge.

Chomsky (2004) is also critical of the banking approach because he believes that it hinders the development of critical thinking in children and prevents a child from understanding. He considers it a means to control children's thinking.

Dewey (1990) had similar beliefs in that he too felt that education requires 'doing' and that knowledge is tied to manipulating. He referred to the didactic approach as the 'memorize and drill' method. He was heavily critical of this pedagogy due to its impersonal nature and lack of individualism. Dewey insisted that education should be an active and inquiry-based process whereby children construct meaning and knowledge and that it should take into account children's interests. Dewey, like Freire, valued the social element of constructing knowledge as he discusses the importance of co-operation, communicating, and exchanging ideas.

Dewey (1990), Freire (1970), and Chomsky's (2004) beliefs around education, the construction of knowledge and the social element to learning were echoed in McCoy, Smyth and Banks' (2012) study, which suggests that constructivist learning is where

> the child is seen as an active agent in their own learning, in keeping with constructivist philosophy which regards education as a process in which the child constructs knowledge in interaction with others (p.3) [therefore] learning is an active process and the construction of knowledge is not just an individual process but socially constructed through interaction with peers, teachers, parents and so on (p.23).

Reflection

Having read the above philosophies, it was evident to me that I needed to change my style of teaching and my approach to teaching mathematics. While my approach to teaching was not as negative as is outlined in these philosophies, there was a tendency there to revert to the 'banking approach' and the idea of children receiving knowledge rather than creating it. I feel I was reverting to this traditional style of

teaching because I was experiencing what Lortie (1975) describes as 'The Apprenticeship of Observation'. Teaching in this manner meant that I was experiencing myself as a living contradiction as I value student-centred teaching and its ability to develop critical thinkers. Both of these were being denied when I was using the didactic, teacher centred approach to teaching.

Student-Centred Approach

In order to live up to my value of student-centred education and its ability to develop critical thinkers and to my value of inclusion, I wanted to ensure there was rich mathematical learning taking place for every child in my classroom. I also wanted to implement a teaching pedagogy that, in line with the philosophies of Freire and Dewey, develops critical thinkers rather than passive recipients of knowledge. Thus, I sought to implement a student-centred approach. Slavich & Zimbardo (2012) describe student-centred instruction as an instructional philosophy that aims to position pupils at the centre of inquiry and problem solving. They state that student-centred pedagogies help to support pupils in generating their own strategies to solve cognitively challenging tasks and in constructing their own understanding of mathematics concepts. Darsih (2018) would also agree, stating that learner-centred teaching forces pupils to play an active role in their education, as opposed to being passive recipients of knowledge. This was something I wanted to achieve in my classroom as I moved away from the didactic style of teaching and towards an approach whereby the children had an active part to play in their own learning. Talbert, Hofkens and Wang (2018) describe the benefits associated with implementing a student-centred approach to teaching, stating that this approach can increase pupils' understanding of mathematics concepts and practices and raise their achievement level in mathematics.

Kirschner, Sweller and Clark (2006) argue that children, particularly young children similar to those in my classroom, are novice learners and therefore, when asked to partake in inquiry-based learning, they are relying on their working memory. Kirschner et al. (2006) identify that limitations exist within the working memory when dealing with novel information and that, while 'expert problem solvers derive their skill by drawing on the extensive experience stored in their long-term memory and then quickly select and apply the best procedures for solving problems'(p.76), novice learners have not yet built up this extensive experience and so when involved in inquiry-based learning, which requires 'the learner to search a problem space for problem-relevant information'(p.77), this places 'heavy demands on working memory' (p.77). This 'working memory load does not contribute to the accumulation of knowledge in long-term memory because while working memory is being used to search for problem solutions, it is not available and cannot be used to learn' (Kirschner et al., 2006:77). Hence, the argument is that direct teaching is a more effective approach, particularly for novice learners. Indeed, the authors state that 'when dealing with novel information, learners should be explicitly shown what to do and how to do it' (Kirschner et al., 2006:79) because 'students learn more deeply from strongly guided learning than from discovery' (Kirschner et al., 2006:79). They also debate the idea that inquiry-based learning may result in pupils developing misconceptions and incomplete knowledge.

McCoy, Smyth and Banks' (2012) study, while it does reiterate the philosophies of Freire and Dewey, in that it considers education to be an active process where knowledge is constructed collaboratively, would also agree with Kirschner et al.'s work, as it suggests that 'teachers who emphasised a teacher-directed, basic-skill orientation appeared to be most effective in both mathematics and reading gains'

(McCoy, Smyth and Banks, 2012:23). It also states that ‘a student-centred, advanced-skill focus did not appear to be an effective teaching strategy in these early primary grades’ (McCoy, Smyth and Banks, 2012:23).

Therefore, effective teacher input is essential in order to ensure that the students are conducting knowledge and learning while using the student-centred approach. I effectively helped children to construct their own knowledge using Core Practices.

Core Practices

Darsih (2018) refers to core practices as she describes the role of the teacher in the learner-centred approach as modelling the appropriate expected behaviour for the students; encouraging students to learn from and with each other; and providing more feedback throughout the process. Darsih (2018) notes how implementing these practices in the learner-centred classroom promoted more in-depth learning and facilitated students’ development into independent learners.

Grossman (2018), one of the leading researchers on core practices for teaching, describes core practices as practices that:

- occur with high frequency in the classroom,
- can be enacted across different curricula and instructional approaches,
- enable teachers to learn more about their students and their teaching,
- preserve the integrity and complexity of teaching, and
- are research-based and have the potential to improve student achievement.

Core teaching practices are described by the University of Michigan (2020) as the fundamentals of teaching, which are critical in helping students learn important content and in supporting pupils’ social and emotional development. The University

of Michigan refer to these core practices as the Teaching Works' High-Leverage Practices. They state that these practices are "high-leverage", not only because they matter to pupil learning, but also because they are basic for advancing skill in teaching.

Grossman lists the Teaching Works' High-Leverage Practices in her book. These practices include but are not limited to: 1) leading a discussion, 2) explaining and modelling content, practices and strategies, 3) eliciting and interpreting student thinking, 4) checking for student understanding 5) providing feedback to students and 6) analysing instruction for the purpose of improving it.

1. ***Leading a discussion***

Grossman (2018) states that a discussion is a collective process which enables the teacher and pupils to build knowledge together. The participants practice listening, speaking, and interpreting as they contribute orally, listen actively, and respond to and learn from others' contributions. As such, they use one another's ideas as resources.

2. ***Explaining and modelling content, practices and strategies***

Grossman (2018) highlights explaining and modelling as important teacher practices for making content, practices, and strategies explicit to pupils. She refers to explaining as a simple verbal explanation which is sometimes accompanied by examples or representations. Grossman describes modelling as a more elaborate kind of explanation that includes explaining, but also thinking aloud and demonstrating.

3. ***Eliciting and interpreting student thinking***

It is the role of the teacher to pose questions and set tasks that are carefully selected to draw out a student's thinking, as this enables teachers to 'evaluate student

understanding, guide instructional decisions, and surface ideas that will benefit other students' (Grossman, 2018: 164).

4. Checking for student understanding

Grossman (2018) discusses the importance of checking for understanding regularly throughout the lesson, as she notes that these checks are essential in providing the teacher with the information they need to determine the students' level of competency and thus enable them to adjust instruction accordingly.

5. Providing feedback to students

Effective feedback is another core teaching practice which is very important. Providing students with effective and specific feedback helps to inform the pupil of specific qualities of their work- highlighting areas they are coping well with and areas that need improvement. 'Good feedback is specific, not overwhelming in scope, focused on the academic task, and supports students' perceptions of their own capability' (Grossman, 2018: 168). The teachers must decide the frequency, method, and content of this feedback.

6. Analysing instruction for the purpose of improving it

Grossman (2018) notes that learning to teach is a continual process that requires regular analysis of instruction and its effectiveness. She discusses how teachers are required to study their own teaching in order to identify salient features of the instruction and to make reasoned hypotheses on how to improve.

Reflection

Previous to undertaking this study, I had a very narrow view of what a student-centred classroom would look like. I was of the opinion that this approach involved inquiry-based learning, whereby the children would construct all of the knowledge

and that the teacher would try to have as minimal an input as possible. However, a review of the literature on teaching styles, specifically student-centred teaching and inquiry-based learning, suggest that the role of the teacher is very important when using the student-centred approach and that a certain level of direct teaching is required in order for children to achieve their potential.

Taking the arguments for and against student-centred and inquiry-based learning, I decided to implement the student-centred approach using Grossman's core practices to ensure effective teacher input. I used these practices as a vehicle for acting as a facilitator when implementing the student-centred approach in my teaching practices. This helped me to ensure that the children were constructing meaningful knowledge around mathematical concepts while at the same time developing critical thinking and independent learning skills.

Inclusion

Penner (2018) describes an inclusive classroom as one where learning 'can be accessed by all students in the class, regardless of prior learning history, demographic/social identities, or belief in their ability to succeed' (Penner, 2018: 69) i.e. inclusive classrooms will take whatever means necessary to ensure that learning is made accessible for all pupils. This is echoed by the NCSE (2011), who state that inclusion involves removing barriers so that each learner will be enabled to achieve the maximum benefit from his/her schooling. Therefore, it could be said that, in order to be considered an inclusive classroom it is necessary that all children in the classroom are learning to the best of their ability in a process which involves addressing and responding to the diversity of needs of all learners and whereby pupils feel respected, valued, stimulated and supported in their environment. The NCSE (2011) characterise inclusive schools by the following:

> ‘1) A positive ethos and learning environment whereby all pupils, including those with special educational needs, feel welcome and experience a sense of community and belonging 2) An emphasis on promoting pupils’ participation and active engagement in their learning and in the life of the school 3) A commitment to developing pupils’ academic, social, emotional and independent living skills 4)A focus on high aspirations and on improving outcomes for all pupils’ (NCSE, n.d.).

Reflection

As I have previously mentioned in chapter one, I value inclusion and, thus, I strive to make my classroom an inclusive one whereby all pupils are learning to the best of their ability. The NCSE suggests that schools should consider methodologies best suited to promoting meaningful inclusion in schools. I felt that implementing a more student-centred methodology in my classroom would allow me to live closer to my value of inclusion. As discussed above, student-centred learning enables students to construct their own knowledge rather than being passive recipients of knowledge. It also helps children to become critical thinkers and facilitates the development of independence. This approach made learning more accessible for all children in the class, particularly those children who were lower-performing. These children found the teacher-centred model of instruction very difficult as they were expected to just receive the knowledge from the teacher and they would then struggle to complete tasks in the workbooks, increasingly becoming frustrated as the questions on the page of the textbook got more difficult. The change to a more student-centred approach in the classroom created a positive, welcoming learning environment where participation and active engagement were encouraged and students experienced a sense of success and achievement. This enabled me to live closely to my value of inclusion, as most children were now accessing the learning.

Engagement

There is a strong connection and link between engagement and the student-centred teaching approach which is noted by Brough and Calder (2012) as they discuss how educators in the field of education are suggesting that student-centred inquiry can lead to enhanced student ownership, engagement and understanding and motivation to learn. They also discuss how engagement can lead to enhanced learning opportunities. Talbert, Hofkens and Wang (2018) discuss the four components of engagement: behavioural, emotional, cognitive and social. These four components must be met in order for children to engage effectively. In terms of mathematics, they considered behavioural engagement as referring to involvement and the presence of positive behaviour. They describe emotional engagement as the positive interaction with teachers, peers, and classroom activities, as well as the pupils' emotional relationship with the learning material. Cognitive engagement denotes the pupils' self-regulated learning, use of deep strategies, and ability to use the appropriate strategies to comprehend complex ideas in mathematics. Lastly, social engagement reflects the quality of pupils' social relationships and their willingness to form and maintain relationships while learning. Knowing that students' engagement behaviours contain each of these components, and that these components must be met, will be useful when considering how to respond to them in a student-centred way.

Motivation

An increase in pupil motivation is necessary in order for there to be an increase in pupil engagement. Motivation is linked to student-centred learning. Weimer (2013) notes how student-centred teaching motivates students by giving them some control over learning processes while Talbert, Hofkens and Wang, (2018) state that 'students

report higher levels of intrinsic motivation in academic work when their teachers are using student-centred instructional practices' (Talbert, Hofkens and Wang, 2018: 328). Brough and Calder (2012) also highlight the link between student-centred learning and engagement as they discuss how students' motivation and persistence with tasks have increased when they engaged with the inquiry-based, problem solving learning approach which is evident in a student-centred classroom. Brough and Calder also go on to discuss how a student-centred approach encouraged the children to make suggestions and to ask questions and thus, the children felt that the learning was relevant to their needs and as a result a high level of motivation and engagement was witnessed when using this approach. While Toshalis and Nakkula (2012) state that 'student-centred classrooms that capitalize on the power of self-determination can substantially enhance achievement motivation' (Toshalis and Nakkula, 2012: 10).

Motivation is also connected to engagement as 'the relationship between engagement and motivation is a two way street; improve one and you also improve the other' (Burton, 2013: 1). I hope that by implementing the student-centred approach to teaching mathematics that there will be an increase in motivation amongst the children towards mathematics and thus an increase in engagement.

Conclusion

In this chapter, relevant literature was outlined and reviewed. In the next chapters, I will outline my study, studying myself and the changes I will make in order to try to improve my teaching practice and to try to live more closely to my values. I will be studying my changes through the methodology of action research, which is described in chapter three.

Chapter Three: Methodology

Introduction

This study emerged from a desire to enhance my teaching of mathematics in order to motivate pupils to engage with the subject. Using action research as the overall methodological approach, I engaged in data collection and analysis to answer the following research question:

> *How does enacting rich mathematical teaching and learning affect pupil motivation to engage in mathematics lessons?*

This study was an action research study, whereby I served as both the researcher and the participant as I studied my own practice. Sullivan, Glenn, Roche and McDonagh (2016) discuss how the process involves engaging in a deeply values-based approach to critical reflection on your own work and how it involves you studying yourself, with a view to improving your practice. This study aimed to enhance teaching and learning during my mathematics class by moving away from the traditional, teacher-centred approach to teaching. My Initial Teacher Education course was a strong advocate for student-centred learning and enacting a more student-centred approach during teaching placement. However, growing up as a pupil, I participated in traditional, teacher-centre mathematics lessons and as I came under pressure teaching the three different class levels and fulfilling the role of acting principal, I experienced Lortie's (1975) idea of the 'Apprenticeship of Observation'. I found, from working in many different primary schools, that many teachers experienced similar learning situations in mathematics and, as a result, many of these teachers have also reverted back to the traditional, teacher centred approach. Many of these teachers may be completely unaware that they are teaching in this way and there are some who are

aware but who may not understand the necessity to change, or the potential this change has to positively affect pupils' motivation to engage in mathematics. My study is an attempt to change my practice by implementing rich mathematical teaching and learning using the student-centred approach in order to motivate students to engage in mathematics. However, dissemination of the study will also hopefully make those who read it more aware of the idea of Lortie's Apprenticeship of Observation.

This chapter will describe and justify the methodological choices that were used in this self-study action research study. Included in the methodology are explanations of the different research paradigms, my rationale for using the action research methodology, the context in which the study took place, the ways in which the population and sample were selected, the procedures for data collection, a brief overview of the data analysis procedures, as well as ethical considerations and the research design.

Research Rationale

The study is situated in a context in which I, as a mainstream class teacher, was experiencing myself as a living contradiction, as I was not living to my values of education, specifically student-centred education, and its ability to develop critical thinkers and my value of inclusion. In September 2019, I commenced a new teaching role in a small rural school, where I taught a class of twenty-one pupils which consisted of junior infants, senior infants, and first class. As well as answering the research question's purpose of improving my teaching of mathematics so that pupils are more motivated to engage with the subject, it is my hope that the results of this study will result in a contribution to practice from which current and future teachers might benefit.

Research Paradigms

McNiff (1988) describes the three major research paradigms of educational research as: 1) The Positivist Research Paradigm, 2) The Interpretative Research Paradigm, and 3) The Critical Theoretic/Action Research Paradigm. McNiff (1988) discusses how, what we look for, how we interpret what we see, and how we solve the problems we encounter is all determined by the paradigm of research in which we work.

The Positivist Research Paradigm is primarily used when the researcher collects data and then interprets this data in an objective and rational way. The data collected is observable and quantifiable and, therefore, it can be statistically analysed. In this type of approach, the researcher is independent of the study and there are no provisions for the interests or values of the researcher to be included in the research. As such, it is very factual. The interpretative approach is concerned with philosophical and methodological ways of understanding sociology. Given (2008) discusses how the Interpretative Research Paradigm is closely linked to social sciences and how it involves the researcher fitting their practice on to a particular framework which they have imposed. The Critical Theoretic/Action Research Paradigm is most often used when the researcher is seeking to improve their own practice and, thus, this paradigm was most suited to this research study as I, the practitioner, was conducting the research with the primary goal of improving my teaching practice in the area of mathematics. The Critical Theoretic/Action Research Paradigm is outlined in further detail in the following paragraphs.

Action Research

McNiff (1988) suggested that action research is, ‘a coherent approach to the everyday practice and problems of teachers in ordinary classrooms who are trying to understand, make sense of, and improve their professional lives’ (p. 19).

Coghlan and Brannick (2014) agree with McNiff in defining Action Research in a broad sense, as ‘(1) research in action, rather than research about action; (2) a collaborative democratic partnership; and (3) a sequence of events and an approach to problem solving’ (Coghlan and Brannick, 2014: 6) Research in action, rather than research about action, refers to the idea that the research is carried out directly by those who are experiencing a problem. It is a collaborative process, as the participant is also the researcher rather than the object of the study. Thus, they work alongside colleagues who have agreed to help in offering their support and guidance, by sharing their viewpoints, and by clarifying situations and thoughts. These people are referred to in research as critical friends, someone who will ‘have empathy for the teacher’s research situation and relate closely to his or her concerns, but at the same time are able to provide rich and honest feedback’ (Altrichter, et al., 1993: 61). My critical friend had a clear understanding of the purpose of this study and throughout the collaborative process provided me with a different perspective from which to view the study while also helping me to ensure my viewpoints and thoughts were of a non-biased nature. The final characteristic of action research, as described by Coghlan and Brannick (2014), is that action research involves a sequence of events. The researcher is involved in a sequence of events as they seek to resolve the problem they are encountering by engaging in the cyclical process of planning, taking action, observing, and reflecting.

Action Research 'embraces the idea that each researcher is informed by their own values, norms and assumptions' (Sullivan Glenn, Roche, McDonagh, 2016: 25). By values, we mean, 'the underpinning philosophy of teaching and learning that informs how we act as teachers' (Sullivan, Glenn, Roche, McDonagh, 2016: 12), involving 'an exploration of our own practice, drawing on our values, with a view to improving that practice and generating theory from our learning in that process' (Glenn, Roche, Mc Donagh, Sullivan, 2017: 30). It is very different to other research, in that it 'rejects the notion of an objective, value-free approach to knowledge generation in favour of an explicitly political, socially engaged, and democratic practice' (Brydon-Miller, Greenwood and Maguire, 2003: 15). Effectively, our values establish what kind of teacher we want to be and what we believe to be an effective teacher. When considering what our values are we must ensure that they are 'good' values and to do this we must consider whether they are likely to endure over time, whether they contribute to a greater good and whether they lead to actions that will benefit others in the field. Our values are then used when testing the validity of our claim to new knowledge. My personal values are rooted in the idea that education should develop critical thinkers and the idea of an inclusive classroom. These values were being denied in my teaching practices and this is something that I wanted to change. Thus, the idea of the action research paradigm being centred on my values was something that appealed to me.

The Action Research Paradigm also appealed to me because it allowed me to put the theories around student-centred learning, core practices, inclusion, motivation, and engagement into practice. In addition, as I was researching my own teaching, it meant the theory was no longer disjointed from what was occurring in the classroom. Thus, it enabled the boundaries between theory and practice to be broken and to

‘dissolve and fade away, because theory is lived in practice and practice becomes a form of living theory’ (McNiff, 1988: 35).

Action Research is considered to be qualitative research. Lincoln and Denzin (2011) describe how ‘qualitative researchers study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings people bring to them’ (Lincoln and Denzin, 2011: 3). Lincoln and Denzin further detail how qualitative research ‘involves the studied use and collection of a variety of empirical materials…that describe routine and problematic moments and meanings in individuals' lives’ (Lincoln and Denzin, 2011: 4). Put simply, qualitative research involves researchers using a wide variety of methods in order to come up with a solution to solve a problem they are experiencing in their work or in their lives in general. While, Kennedy and Montgomery (2018) from The Teaching Council characterise qualitative research as research which captures the perspective of the individual researcher, it is closer to real life experiences, as it sets out to provide a solution to everyday constraints, is concerned with the richness of description, and is generally less likely to be generalised due to the individualised and subjective nature of the study. They then go on to state that qualitative research often takes place in a naturalistic setting where soft data i.e. words, sentences symbols etc. are collected and where the researcher has less control over the outcome thus, making it a greater reflection of real world circumstances. Kennedy and Montgomery (2018) discuss how qualitative research is different to quantitative research in that the lather is deductive, objective, concerns numbers and figures and is generalizable. As action research fits the descriptions outlined by both Lincoln and Denzin (2011) and Kennedy and Montgomery (2018), it can therefore be considered one approach to qualitative research.

There are many benefits to qualitative research, and more specifically action research. Kennedy and Montgomery (2018) discuss these benefits mentioning the possibility to generate rich, detailed information and understanding, the research's ability to include and consider the views, values, interests, and perspective of the researcher and the fact that the research is more realistic and reflective of real world circumstances. However, it is important to remember that there are also limitations to qualitative research, which Kennedy and Montgomery (2018) also discuss, including the questions raised around the reliability and validity of this type of research and the potential for researcher bias in the study which I will discuss in further detail in the next section entitled 'Trustworthiness'.

Brydon-Miller, Greenwood and Maguire (2003) would agree with Kennedy and Montgomery, as they also recognise localism and the difficulty in intervening in large-scale social change efforts as weaknesses of action research. Indeed, the 'bulk of action research takes place on a case by case basis, often doing great good in a local situation but then failing to extend beyond that local context' (Brydon-Miller, Greenwood and Maguire, 2003: 27). I plan on overcoming this limitation by disseminating my research, which I will discuss in further detail in later chapters.

Trustworthiness

As I previously stated, I value education and its ability to develop critical thinkers. I also place huge importance on the value of inclusion and on the idea of an inclusive classroom. I will use these values to assess the trustworthiness of this study.

Mertler (2012) describes rigor as the extent to which research reaches standards of validity, quality, credibility, and accuracy. Rigor in action research is very different to that in traditional research. Action research is judged in terms of its trustworthiness. Trustworthiness implies that the research does not reflect personal

biases, opinions, and perspectives. To ensure trustworthiness the researcher must show validity, credibility, transferability, and dependability.

Validity is an indication of how sound and accurate your research is. In order to show validity in your action research project, you must be able to show 'that you have moved towards a situation in which you are living your values more fully in your practice.' (McNiff and Whitehead, 2010: 14) To show the validity of your research, you must do a personal validity check whereby you ask yourself 'can you show to your own satisfaction that you are trying to live your values more fully in your practice?' (McNiff and Whitehead, 2010: 15) and a public validity check where you ask ': can you show this to other people's satisfaction?' (McNiff and Whitehead, 2010: 15). This move towards living more closely to my values is evident in my reflective journal, my lesson plans and lesson reflections, as well as the notes from my critical friend and in the results from the Learner-Centred Rubrics for Classroom Observations.

One must also show the credibility of their research. Credibility refers to the plausibility and integrity of the study. To prove the credibility it was necessary for me to produce 'an evidence base that shows how you have engaged with the question and have transformed it into a knowledge claim' (McNiff and Whitehead, 2010: 99) and to present this evidence to others so they can confirm and critique the changes in your work and in your thoughts and attitudes towards your work. Sullivan et al. (2016) suggest sharing your work on refereed journals or ejournals and at educational conferences in order to open your work for academic critique. On completion of this study, I could share my work at conferences such as the Irish National Teachers' Organisation (INTO) conference, with the Network of Educational Action Research in Ireland (NEARI), with the World Map Action

Learning and Action Research Association (ALARA), as well as in referred journals and with colleagues at planning meetings and in teacher education centres. These would provide me with opportunities for public critique and, thus, will increase the credibility of the study.

Transferability refers to the degree to which the results of a study can be generalised and while we discuss action research as relevant to our own practice in our own context it is still possible for it to be transferable in that others who familiarise themselves with the study can decide whether their personal situation is similar enough to the one in this study and whether the outcomes can be applied. Therefore, transferability does exist within this study because the outcomes of this action research could potentially be applied to other mathematics classrooms. In order to make this study accessible for other teachers to be able to potentially apply it in their classrooms, it is necessary for me to disseminate my research. Dissemination is the sharing of research with people who can make use of it. This aids the transferability of this study because 'by disseminating action research, researchers contribute to a body of knowledge that can advance a field, inform theoretical development and create change' (Coghlan and Brydon-Miller, 2014: 277). Teachers who access this study can transfer it to their own situation and, thus, make changes to their teaching.

Dependability is concerned with the consistency and reliability of the research 'and the degree to which research procedures are documented, allowing someone outside the research to follow, audit, and critique the research process' (Moon et al., 2016: 2). This dissertation provides detailed coverage of the employed research design and implementation, including the methodology and methods, and the details of data collection procedures and thus increases dependability by increasing transparency.

Triangulation is also necessary in order for the researcher to show trustworthiness. Triangulation 'is not a tool or a strategy of validation, but an alternative to validation. The combination of multiple methods, empirical materials, perspectives and observers in a single study is best understood, then, as a strategy that adds rigor, breadth, and depth to any investigation' (Lincoln and Denzin, 2011: 5). Triangulation gives more than one viewpoint or perspective on the changes you have made which makes your work more trustworthy as the changes are viewed from more than one standpoint. It is important to collect data and then cross check this data with other people. This is where a critical friend plays a crucial role because 'documenting what a critical friend says is a useful data-gathering tool [and] by including their comments in your research report you are adding another perspective that can validate your work' (Sullivan et al., 2016:82). It is also helpful to check the perspective of the pupils throughout the research. Comparing the perspective of my pupils against my own stance and that of my critical friend will aid me in triangulating my data. Using multiple sources of data collection, including both qualitative and quantitative methods, is also helpful in enabling me to triangulate the data. Sullivan et al. (2016) refer to this as methodological triangulation.

Conclusion

Finally, action research is a self-reflective process that involves continually evaluating practices, solutions, and the researcher herself, with a view to improve the quality of the situation (McNiff, 1988). Unlike more traditional forms of educational research, action research is carried out "on-the job", whereby researchers study their own practice. According to Patrizio, Ballock & McNary (2011), studying our practice means studying ourselves. In the case of my study, my unit of analysis was myself, the teacher, engaged in my classroom while focusing on the critical question

that action researchers pose, 'How do I improve what I am doing?' (Whitehead, 1993). Due to the fact that one is studying one's own practice, the researcher must show validity, credibility, transferability, and dependability to ensure trustworthiness.

Action Research Model

The model of Action Research I used for the purpose of this study was a basic action research model which was adapted from that of Kurt Lewin's Model (1946), Kemmis and McTaggart's Model (1988) and Whitehead and McNiff's (2006) action research cycle. This model consists of a four step cyclical approach to action research involving reflecting, planning, acting, and observing. Kurt Lewin's Model (1946) model can be seen in Figure 3.1., and this later extended into ongoing action research cycles, as can be seen in Figure 3.2. Kemmis and McTaggart's model is displayed in Figure 3.3. Lastly, Whitehead and McNiff's Model (2006) is seen in Figure 3.4.

Kurt Lewin's Model (1946)

Burnes (2004) describes how Kurt Lewin is considered the father of action research as he first coined the term 'action research' in 1944. Lewin's (1946) Model is an action-reflection cycle of planning, acting, observing and reflecting which was later expanded into ongoing action-reflection cycles as can be seen in the figures below.

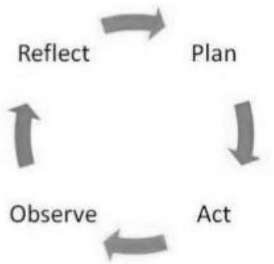

Figure 3.1. Kurt Lewin's Model (1946) is an action-reflection cycle of planning, acting, observing and reflecting.

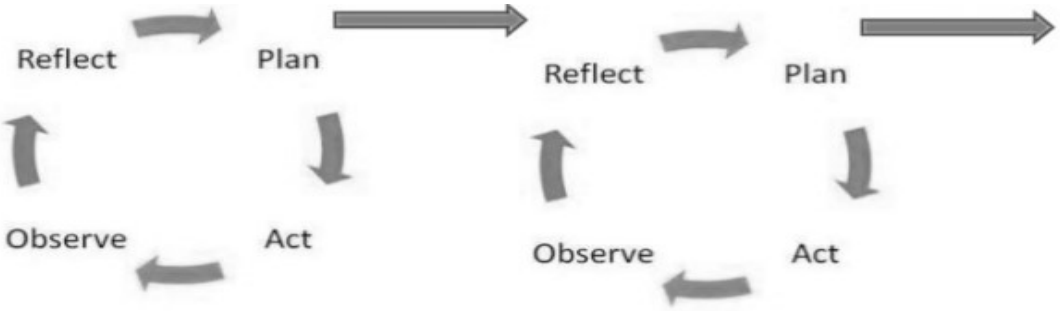

Figure 3.2. How Kurt Lewin's Model (1946) later extended into ongoing action research cycles.

Kemmis and McTaggart's Model (1988)

Kemmis and McTaggart's Model (1988) is similar to that of Kurt Lewin, as it is a cyclical process involving four steps. Burns (2010) explains how Kemmis and McTaggart (1988) describe action research as 'a dynamic and complementary process, which consists of four essential 'moments': of planning, action, observation and reflection' (Burns, 1999: 32). Kemmis and McTaggart's model can be seen in Figure 3.3.

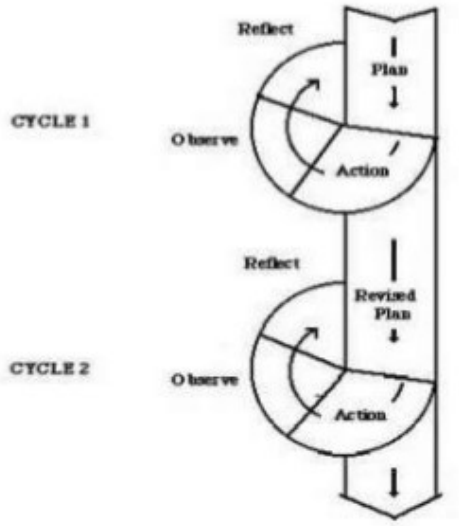

Figure 3.3. Kemmis and McTaggart's Model (1988).

Whitehead and McNiff's Model (2006)

Whitehead and McNiff's Model (2006) is slightly different from the previous two models I have discussed in that it contains five steps. These steps include observing, reflecting, acting, evaluating, and modifying the action in order to move in new and improved directions. While this model has an extra step, this last step is similar to the previous models, in that it allows for ongoing action-reflection and it leads into the next cycle.

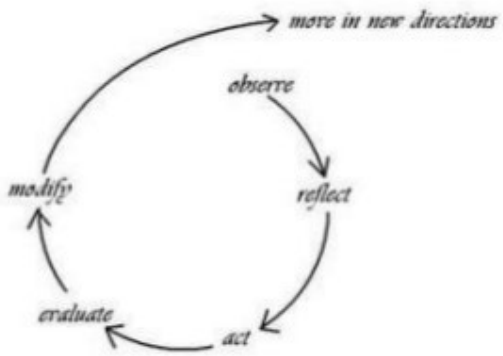

Figure 3.4. Whitehead and McNiff's (2006) action research cycle.

Research Site and Research Participants

The research took place in a co-educational, rural national school where there were approximately seventy pupils in the school, as well as three mainstream class teachers and two special education teachers. At the time of the study, I was teaching junior infants, senior infants and first class. There were twenty one pupils in my class altogether, ranging in age from four to eight. Table 3.1 shows the breakdown of numbers in each class.

Class Level	No. of Pupils
Junior Infants	6 -3 girls, 3 boys
Senior Infants	6 -1 girl, 5 boys
First Class	9 – 6 girls, 3 boys

Table 3.1 The number of pupils in each class.

Ethical approval was granted for all of these children to participate in my research. In order to obtain this ethical approval, I had to begin by seeking the permission of Maynooth University to undertake this research. To do this, I had to fill out the Ethics Approval for Master of Education form (Appendix A). Having received permission from the college to complete this research I then had to seek approval from the Board of Management of the School (Appendix B), as well as the legal guardians of the children in my class (Appendix C) and the children themselves (Appendix D). The main participants of my research were the nine pupils in first class. I chose to focus on these pupils because I felt this was more manageable and would reduce complexity, thus, providing me with more accurate results. This type of sampling is known as purposive sampling. Purposive sampling is where the 'researcher selects people according to the aims of the research' (Coyne, 1997: 624). It therefore constitutes non-probability sampling i.e. not random sampling.

Description of Intervention

In this study, I aimed to implement rich mathematical teaching and learning, by moving away from a didactic style of teaching and adapting a more student-centred approach, to motivate pupils to engage in mathematics. The intervention took place in my own classroom whereby I acted as both the researcher and the participant. Information was gathered from the pupils but only used to inform my teaching practices. The intervention took place over two cycles during a period of seven

weeks from the 27th January to the 12th March and consisted of three lessons a week. Figure 3.5 shows a timeline of the intervention that took place.

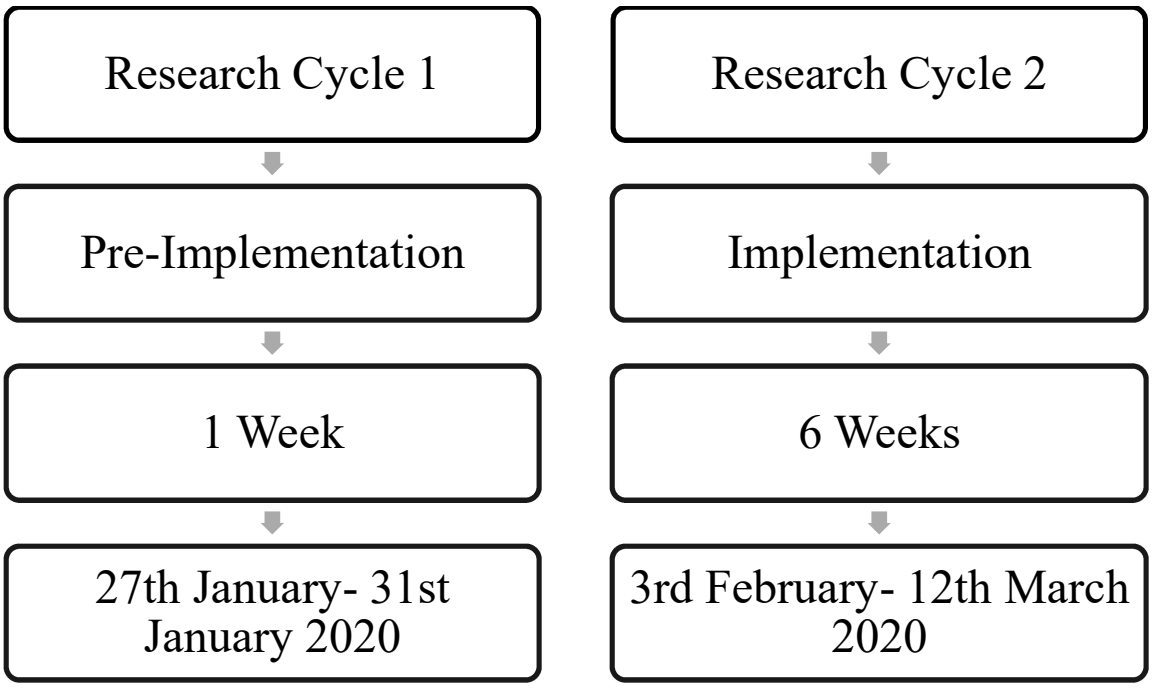

Figure 3.5. Timeline of the Intervention

Research Cycle 1

Research cycle 1 took place over 1 week from the 27th January to the 31st of January 2020 and consisted of three lessons. During research cycle 1, which I have termed 'pre-implementation', I continued with the traditional style of teaching which I was previously implementing. Lessons were teacher centred and involved the children engaging in a passive process whereby they were receiving knowledge rather than creating it. During this stage data was collected which was later compared with the data collected in research cycle 2. The data collection methods are explained in a later section of this chapter.

Research Cycle 2

Research cycle 2 involved changes being implemented to the way in which I was teaching mathematics. This cycle consisted of eighteen lessons which took place over six weeks from the 3rd of February to the 12th March. During this cycle, I wanted to implement rich mathematical teaching and learning by moving away from the traditional, didactic style of teaching and towards a more student-centred approach. In order to do this, I planned my lessons using three main resources – core practices, Gladis Kersaint's (2019) '100 Questions that Promote Mathematical Discourse' and the PDST Numeracy Handbooks. These resources were invaluable to me when planning for a more student-centred approach.

The core practices were important as they not only matter to pupil learning, but are also basic for advancing skill in teaching. The core practices I used have previously been outlined in chapter two.

The second resource I used was Gladis Kersaint's (2019) '100 Questions that Promote Mathematical Discourse'. These questions allow pupils to share their knowledge in a way that highlights their true understanding and uncovers their misunderstandings in mathematics and in a way that helps to promote mathematical thinking and encouraging classroom discourse.

The final resource I used when planning my lessons during cycle 2 were the PDST Numeracy Handbooks (Manuals | PDST, n.d.). These handbooks were used to support and develop mathematical thinking and to enhance the teaching and learning of mathematics in my primary school classrooms. They provided me with the fundamental facts for each of the strands, the common misconceptions the pupils may have encountered, teaching notes, sample teaching and learning experiences and

consolidation activities. This resource enabled me to implement lessons that included inquiry-based, active and hands-on learning activities that were student-centred.

All of the above enabled me to implement a more student-centred approach to teaching. The children really enjoyed this approach and, thus, it lead to an increase in pupils' motivation to engage in mathematics class.

Data Collection

As action researchers, we must gather data in order to show the changes we have made to our practice and to show that we are now acting more closely in the direction of our values in order for us to be able to make a claim to knowledge.

Over the course of this study, I collected data using many different data-collecting tools, some of which were qualitative by nature and others which were quantitative. Qualitative data consists of 'information that can't actually be measured and is about qualities' (Sullivan et al, 2016:85) while quantitative data is 'something that can be measured and written down with numbers' (Sullivan et al., 2016:85). Some of the data collecting tools directly involved myself such as my reflective journal and my lesson plans. Other data sources involved the pupils but were solely for the purpose of improving my teaching, as I was the participant in the study and, thus, I was researching my own practices. These data sources included student questionnaires, observations, notes from student-teacher conferences, and notes from group interviews. Data was also collected from my colleague who acted as a critical friend. This data was helpful in allowing me to triangulate the data I had collected and in minimising bias.

Figure 3.6 shows a breakdown of qualitative and quantitative data collection methods. Using multiple data collection sources provided a variety of data to give a

more thorough perspective of the research problem and data to analyse for the results of the intervention.

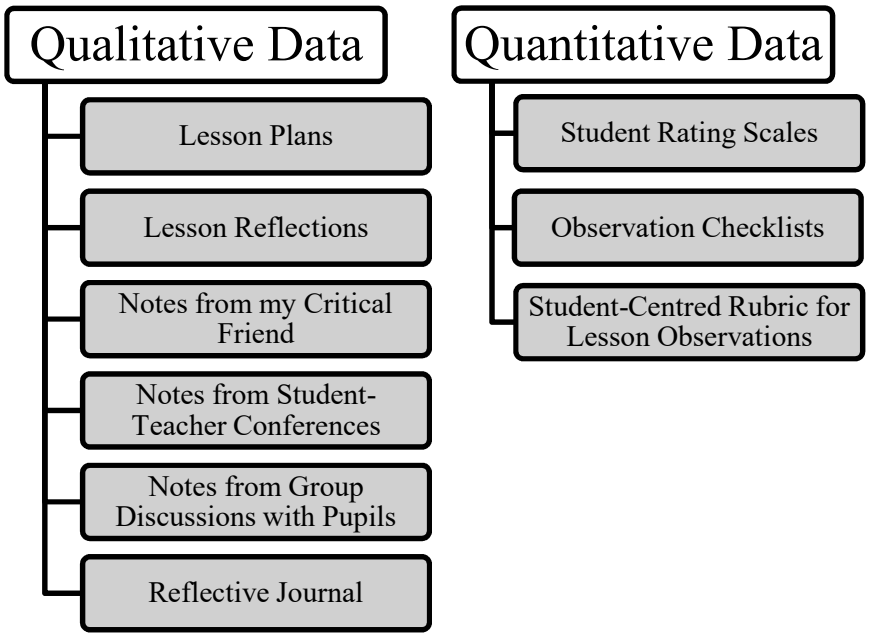

Figure 3.6 A breakdown of qualitative and quantitative data collection tools.

Gathering data was very important, enabling me to evaluate whether or not I am now living more closely to my values, providing evidence of change in my practice.

Each of the data collection tools used in this study is outlined in the following section.

Surveys / Rating Scales

Surveys involve questioning people on a topic and then analysing the responses they have given to these questions. I chose to use surveys because, as Bhattacherjee (2012) discusses, they have several inherent strengths compared to other research methods. Surveys are an excellent vehicle for measuring a wide variety of unobservable data, such as people's attitudes and beliefs. Surveys reflect the attitude and feelings of people towards the topic and so it can be said that surveys make

thoughts and feelings visible. The children were asked to complete a survey in the form of a rating scale at the end of each lesson as it enabled them to demonstrate their feeling and whether or not they were enjoying mathematics lessons. Enjoyment is important for this study as I seek to enhance the pupils' motivation to engage in mathematics and 'a reasonable assumption is that intrinsic motivation –the enjoyment of working with mathematics – influences students' motivated behavior (effort, persistence, and help-seeking behaviour)' (Skaalvik, Federici and Klassen, 2015: 131). Skaalvik, Federici and Klassen's (2015) belief that enjoyment influences motivation is in agreeance with Reeve (1989) who also believes there is a link between enjoyment and motivation stating that 'enjoyment contributes to intrinsic motivation by sustaining the willingness to continue and persist in the activity' (Reeve, 1989: 83). Figure 3.7 shows the rating scale which was presented to the children. The children were asked the question 'How did you enjoy today's mathematics lesson?' and asked to circle the face which best corresponds with their answer to this question. I assigned each face a corresponding label which I explained to the children previously. These labels allowed me to analyse this data using a quantitative approach. Figure 3.8 shows the corresponding labels which were assigned to each face.

Figure 3.7 Children's Rating Scales

				
Awful	Not very Good	Good	Really Good	Excellent

Figure 3.8 Corresponding labels for each face

The student rating scales allowed me to determine the level of enjoyment the children encountered during math lessons. This was one element which enabled me to determine the level of motivation from the children as enjoyment is linked to motivation.

Student-Teacher Conference/ Group Discussions

Student-teacher conferences are one-to-one conversations between a pupil and the teacher Student-teacher conferences allow greater communication. Communication is important as it enables teacher to establish 'an effective and affective communication relationship with the learner so that the learner has the opportunity to achieve the optimum of success in the instructional environment' (Wrench, Richmond and Gorhan, 2009: 1). The group discussions I used in this study were similar to student-teacher conferences but, instead of the conversation occurring between the teacher and one pupil, the conversations took place between the teacher and several pupils. In this study, the notes I took from student-teacher conferences and group discussions provided further evidence for the data I collected using the rating scales, as it gave children the opportunity to express their feelings, as well as their ideas and opinions, in more detail.

Observational Notes

Observation, as the name suggests, is a method of collecting data through observing. The researcher takes notes in the setting in which their participants are. These notes record visible actions and behaviours of certain individuals or groups or of the whole class. In my observations, I was looking for the level of children's engagement in the lesson while also taking note of their enjoyment. To do this I used an observation checklist (Appendix E). This observation checklist was designed around that of Baumfield, Hall & Wall (2013) (Appendix F). I used the model of Baumfield, Hall & Wall (2013) as a basis for designing my own checklist because I felt that monitoring the behaviours outlined in this model would allow me to determine the level of engagement from the children. The observation checklists allowed me to determine the engagement level of the children in the lessons as the checklists consisted of both positive and negative behaviours that were directly related to the engagement of the child. This enabled me to determine whether there was a change in engagement levels over the course of the intervention. Figure 4.3 shows a list of the behaviours; those on the left are positive behaviours that suggest that the child is engaged in the maths lesson while those on the right are negative behaviours which would imply disengagement in the lesson.

Positive Behaviours	**Negative Behaviours**
Talk related to task	Talk not task related
Answering questions	Wandering around the room
Engaged in task/work	Attempting to distract others
Listening well	Day dreaming/ disengaged

Table 3.2 The behaviours listed on the observation checklist.

Teacher's Reflective Journals

Lew and Schmidt (2011) discuss how reflective journals encourage the researcher to record self-reflection about how learning took place and what was learned. Self-reflection involves thinking about your own teaching and learning and being able to comment and critique these processes. Self-reflection can often show the researcher whether or not they are living to their values and can also show a change in thinking and reasons for this change. I did not visit my reflective journals daily but rather when I felt it necessary; for example, when I felt a significant learning moment had occurred. When writing in my reflective journal, I asked myself questions such as, What did I do? Why did I do it? What did I learn? What was the significance of what I learned? My reflective journal showed a change in thinking in terms of my teaching.

Lesson Plans and Lesson Reflections

As stated previously, my lessons were planned using different resources in order to move in the direction of a student-centred teaching approach. I reflected on my lessons in order to inform further lessons and teaching practices. Similar to my reflective journal the lesson plans and lesson reflections show a change in thinking in terms of my teaching. These lesson reflections were guided by my values, my implementation of the student-centred approach, the children's engagement, and my use of the three resources I discussed earlier in this chapter. They portray a teaching style that is closely linked to the values I hold.

Learner Centred Rubric

This rubric (See Appendix G) was developed to allow teachers to determine how learner-centred their teaching is. It is based on the work of Weimar (2013) and outlines a series of statements. The teacher is asked to select the most suitable

statement under each of the nineteen categories and a formula is then used to calculate whether your teaching is learner-centred, transitional, or teacher-centred. The rubric is broken into three columns: learner-centred, transitional, and teacher-centred. The teacher is then asked to select the most appropriate statement under each category. In order to calculate the score the teacher must add up the number of statements they have chosen in each category and multiple the sum by two for the learner centred column, by one for the transitional centred column and by zero for the teacher-centred column. Then one must add up the total score. If the score is between zero and thirteen this indicates a teacher-centred type of class, fourteen to twenty five suggests a transitional type of classroom while a score of twenty six to thirty eight implies that your classroom is learner-centred. I asked my critical friend to do lesson observations in my classroom and to fill out the rubric for me and to calculate the scores in order to try to minimise bias.

Data Analysis

The qualitative data was analysed by means of thematic analysis. Braun and Clarke (2013) describe thematic analysis as a way of identifying patterns in data and they outline six different phases one must go through when conducting thematic analysis. Braun, Clarke, Hayfield and Terry (2019) note how this six-step approach is recursive and reflective rather than strictly linear. They list the steps as familiarisation, generating codes, constructing themes (not searching for themes as was originally stated by Braun and Clarke in their 2006 paper), revising and defining themes, and finally producing the report.

Ethical Considerations

Just as with other research methods, action research requires researchers to follow a code of ethics. Sullivan et al. (2016) discuss three reasons why ethical standards are

necessary; first to protect the rights of the participants, second to ensure accuracy and to help define action research as a rigorous form of research and lastly, to protect individual and intellectual property rights.

Assent

Permission to carry out this action research was sought from the Board of Management, School Principal, the Parents of the Children involved, the Children themselves, and any other person deemed necessary by relevant school policies and documents. The children were given the right to informed consent, prior to the commencement of the study, in a manner suited to their age, maturity, and competence. Informed consent is 'the provision of information to participants about the purpose of the research, its procedures, potential risks, benefits, and alternatives, so that the individual understands this information and can make a voluntary decision whether to enrol and continue to participate' (Gelling and Munn-Giddings, 2011: 104). To do this, I explained to the children exactly what was involved in the study and I made it clear to the children that the focus was not going to be on them but instead I needed their help in order to become a better teacher, because as Doyle (2007) states 'while the research may be part of the teacher's professional development, the children are not there for the teacher's development. The opposite is the case. The teacher is there for the development of the children' (p. 77). I used child appropriate language when explaining it to the whole class at first and again when explaining it to each child individually. I asked the parents to speak to the children before the children gave their consent to participate in the study. Parents/guardians were given the option of being able to withdraw their consent for their child's participation at any stage during the research should they wish and participants themselves were also given this right. A young person's right refuse to

participate or to discontinue participation was respected even if parents or responsible others had given consent. As mentioned by Gelling and Munn-Giddings (2011) consent must be an ongoing process of negotiation because the future direction of an action research study is often unknown and thus, the consequences of the study might also be unknown. I engaged the children in ongoing process of negotiation as I continually reminded the children and parents of the study that was happening in the classroom and I continually asked if they were still willing to participate in this study.

Vulnerability

The research involves children under the age of 18 years and therefore these participants are considered vulnerable persons. Sullivan et al. (2016) discuss the importance of taking special precautions with vulnerable participants in order to show respect for human dignity. Prior to commencing this research, I carried out a risk assessment which enabled me to identify potential risks this study may pose. I then put risk management procedures in place in order to try to minimise the risks that the study may present. These procedures are listed in Appendix H.

Sensitivity

There was no predictable disadvantage or harm arising from the process or reporting of the research that could not be managed. The nature of this research meant that I was still continuing my everyday teaching, with the only change being the change in methodology. This change in methodology was new to participants. In order to help overcome children's worries around this new methodology I took the advice of the Bright Horizons Educational Team (2020) who offer tips on how to help children cope with change. They suggest giving advance warning of the change, keep as much the same as possible, answer their questions, expect that some regression might

happen and be accepting of grieving and try to remind the child of all the positives. Thus, in order to help the children in my class overcome this change in my teaching approach I made sure to clearly explain to the children the change that was going to take place and the rationale for the change, I explained to them that I would still be teaching them and that we would still be doing maths every day and the only change would be the way in which I am teaching the maths. I also took time to answer the children's questions and to reassure them when they expressed feelings of worry.

Power

Given the age of the children with whom I am working it is important that I acknowledge the power relations at work in this situation and what Sullivan et al. (2016) refer to as the imbalance of power i.e. the balance of power being in favour of me. Because of this, I must always take great care to act in ways that respect the child's dignity and agency. Power dynamics may also be addressed appropriately by, for example, making the researcher role very explicit. The British Education Research Association (2011) guidelines discuss how the best interests of the child should be the primary consideration, and children, who are capable of forming their own views, should be granted the opportunity and the right to express these views freely in all matters which affect them. While the Children First (2011) guidelines suggest the use of a child-centred, inclusive approach to teaching in order to minimise and avoid risks to children.

Data storage

I will ensure that all data is kept secure by using secure computer networks, ensuring that data is stored in a locked cabinet within a locked room, using password protection and data encryption, using courier or secure electronic transfer when moving data, anonymising records and ensuring that any third-party users of the data

agree to a data-sharing agreement so that the same assurances are given for the protection of data.

I recognise that GDPR confers the right to private citizens to have access to any personal data that is stored, and which relates to them. In line with Maynooth University guidelines, as of September 2018, data (anonymised where relevant and feasible) will be stored in a safe, secure, and accessible form and will be held for a period of six years following publication.

Data collected is adequate, relevant, and not excessive and I had a clear purpose for the obtaining of data. Data was used in ways compatible with the purpose for which it was initially given.

Confidentiality

There are different forms of confidentiality including; confidentiality of information, of identity and of data. Confidentiality of information means that you will only discuss 'information which is in the public domain and within the law' (McNiff and Whitehead, 2010: 77). Confidentiality of identity requires that you do not reveal the real names of people or places or anything that would enable someone to identify the participants. Finally, confidentiality of data means that you must have permission to use first-hand data such as transcripts and voice recordings.

Participants were given the right to anonymity. I protected the identity of the school and the children by not providing any specific details or personal information about the school or the children involved in my research. Instead, I took the stance of Sullivan et al. (2016) and, to ensure pupils were not identifiable, I assigned each pupil involved a number.

However, confidentiality could not be guaranteed. It is important for me to remember that as a researcher I may be under statutory duty to disclose confidential information to relevant authorities, and that I must be aware of these responsibilities. I will seek advice from a relevant responsible person before proceeding to disclose any information if and when appropriate. Insofar as it does not undermine or obviate the disclosure, or jeopardise my safety, I should inform the participants, or their guardians or responsible others, of my intentions and reasons for disclosure.

I will not take the decision to override agreements on confidentiality and anonymity where necessary without careful and thorough deliberation.

Conclusion

Chapter three has outlined the research rationale, research paradigms, the research design, data collection methods and ethical considerations involved in this study. The research involves an intervention of seven weeks which is broken up into two different action research cycles. The main tools for collecting data include; observations, rating scales, notes from student-teacher conferences and group discussions, my reflective journal, notes from my critical friend, lesson plans and reflections and the Student-Centred Rubric for Lesson Observations.

Chapter Four Data Analysis and Results

Introduction

In this chapter, I will review the research question and discuss the findings. The purpose of this action research study is to answer the following research question:

> *How does enacting rich mathematical teaching and learning affect pupils' motivation to engage in mathematics?*

This chapter provides a presentation of the data and a discussion of the themes that emerged through the data analysis and how they shed light on the research question. Analysis of the data also resulted in some unexpected findings, in that one child showed a decrease in his level of engagement in and enjoyment of mathematics lessons, which will also be discussed.

Summary of the Data

Data was collected across action research cycle one, where my practice remained unchanged and was a traditional, didactic approach to teaching. Data was then collected in action research cycle two, where the intervention was implemented. The data collected was derived from quantitative and qualitative data collection methods, which have been discussed in the previous chapter.

Quantitative Data

The student rating scales, teacher observation rating scales and the Student-Centred Rubric for Lesson Observations were quantitative data collection methods and were therefore analysed using statistics.

Rating Scales

As discussed in chapter three, the rating scales were used to demonstrate the children's enjoyment of mathematics. The data collected using the rating scales is shown in Figure 4.1. As you will see from the graph below, the children's enjoyment of maths lessons increased significantly over the course of the intervention. The data on the left hand side of the line is the data that was collected in Week 1. This was research cycle one which was pre-intervention and thus the traditional style of teaching was still being implemented. The data on the right hand side of the line is the data collected in research cycle two when the intervention was being implemented, thus I was using a more student-centred approach to teaching.

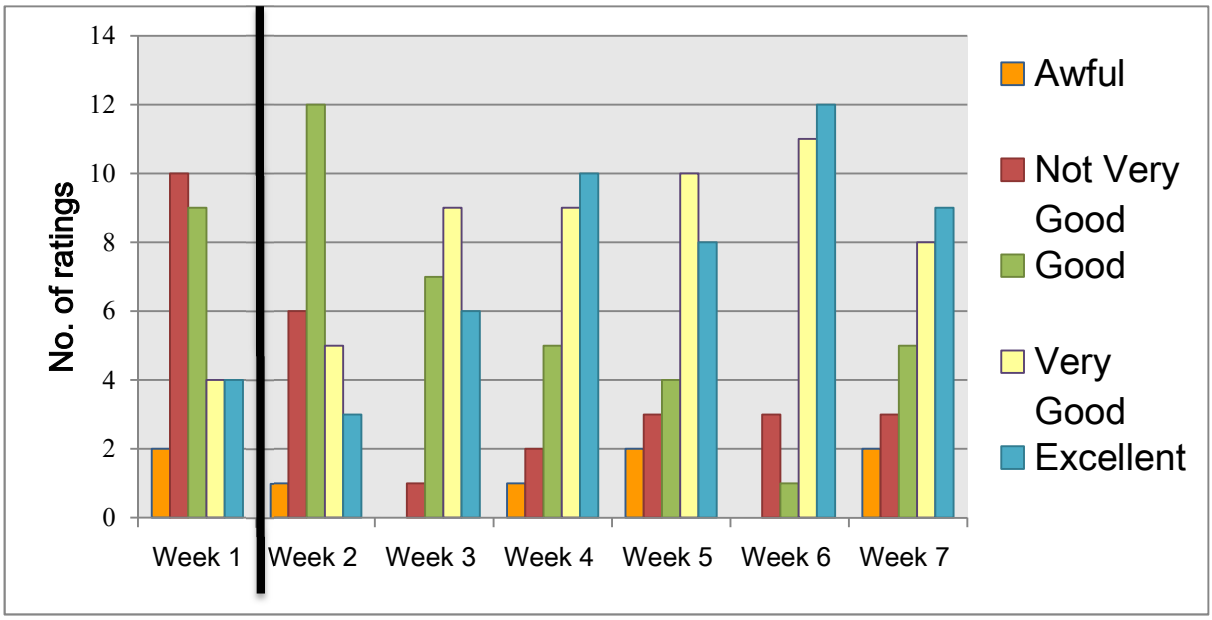

Figure 4.1 The results from the student rating scales.

Observation Checklists

The observation checklists, which I outlined in chapter three, were used in action research cycles 1 and 2 of this study. As can be seen in Figure 4.2, there is a noteworthy increase in the number of positive behaviours between cycle 1 and cycle

2. Cycle 1 took place in week 1 and consisted of a continuation of the traditional style of teaching I was implementing. Cycle 2, which took place over the remaining six weeks, was when the intervention was being implemented. However, more interestingly, as seen in Figure 4.3, is the stark decrease in the number of negative behaviours that occurred in cycle 2 in comparison to cycle 1. This confirmed for me that the children were more engaged in the mathematics lessons during cycle 2. Again, the data on the left hand side of the line is the data that was collected in Week 1, which was pre-intervention and the data on the right hand side of the line is the data collected in research cycle two, when the intervention was being implemented.

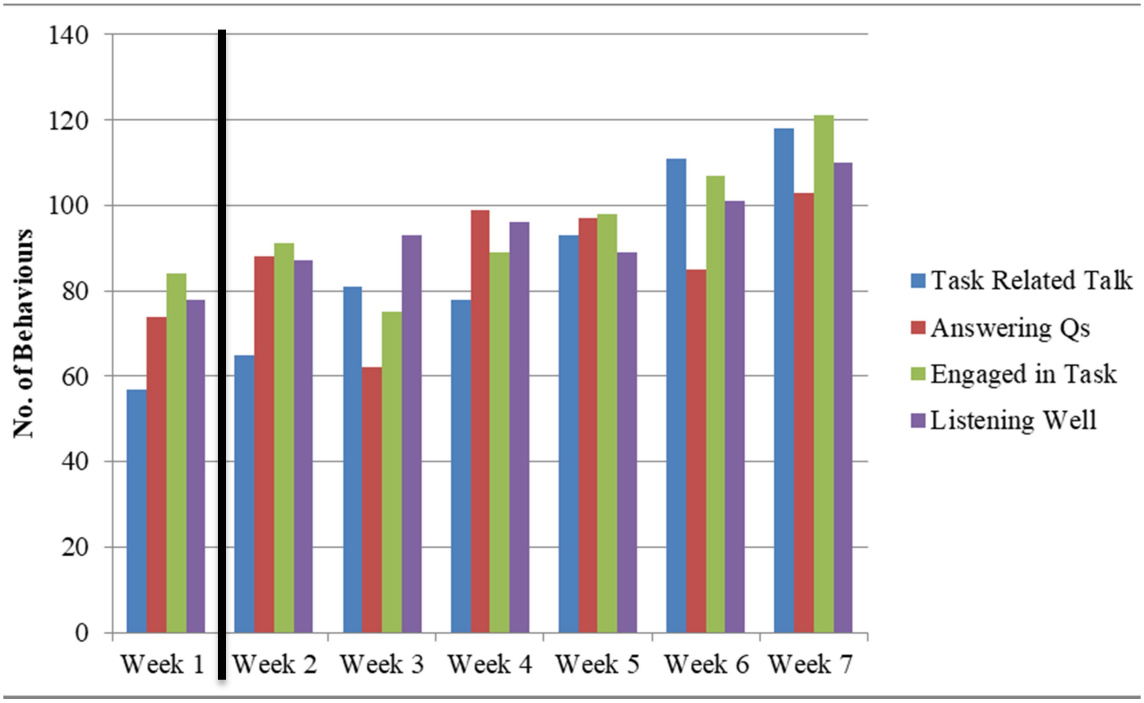

Figure 4.2 The number of positive behaviours observed over the course of the intervention

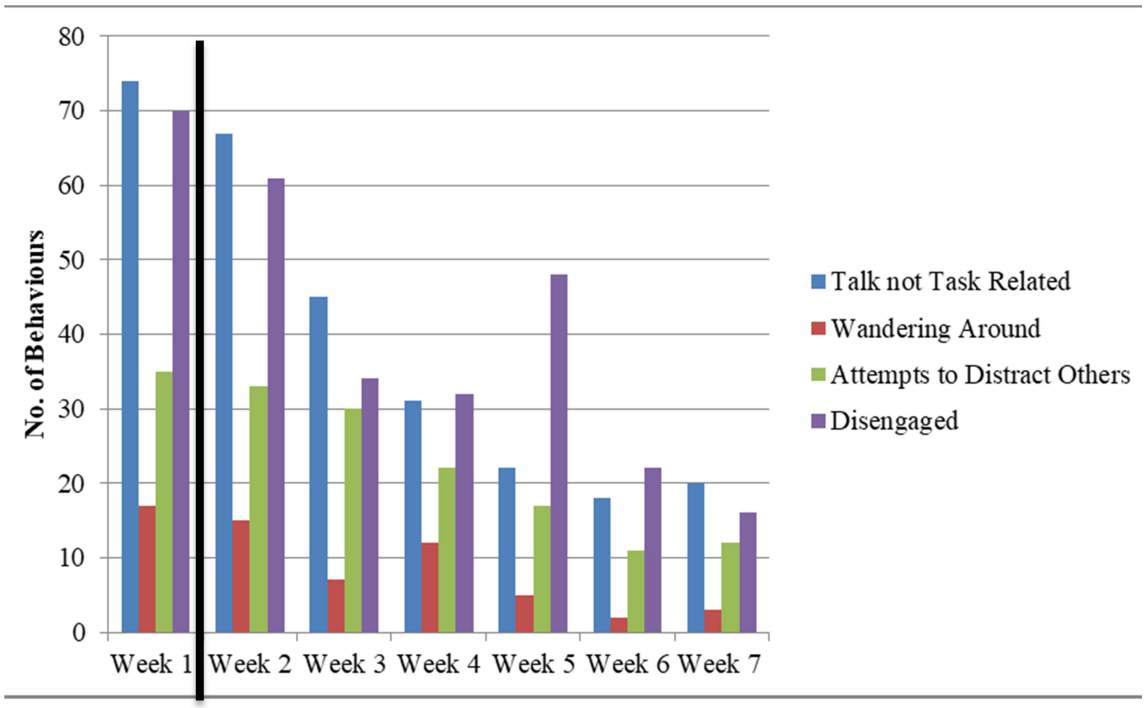

Figure 4.3 The number of negative behaviours observed over the course of the intervention

Learner Centred Rubric

Using the method I outlined in chapter three my critical friend calculated the scores of the rubrics. During research cycle 1, I got a score of 13, which would indicate a teacher-centred approach to teaching. A follow-up observation in week 4 resulted in a score of 28 which did indicate a learner-centred approach, but it only barely made it into this category, being just 2 points over that of the transitional style. Finally, in week 6 during my last observation, I received a score of 33, which again indicated a student-centred approach to teaching. This was a significant change for me, as it indicated that my teaching had moved from a teacher-centred approach, through the transitional style and was now that of a more student-centred approach.

Qualitative Data

Themes

As I conducted thematic analysis using Braun et al. (2019) six steps, I assigned codes to units of text from lesson plans, lesson reflections, journal entries, lesson observations, and notes from my critical friend, as well as from student-teacher conferences and group discussions. This formed the basis for refining the codes and eventually identifying themes throughout the data sets. A sample of the initial and refined codes, which were common across all data sets, as well as the eventual themes which emerged from these codes, are highlighted in Figures 4.4, 4.5, and 4.6, below. Figure 4.4 shows the initial and refined codes which led me to the construction of the theme, 'Student-Centred Learning'. Figure 4.5 is representative of the codes which led to the theme of 'Engagement'. Lastly, Figure 4.6 is a list of initial and refined codes for the construction of the theme of 'Motivation'

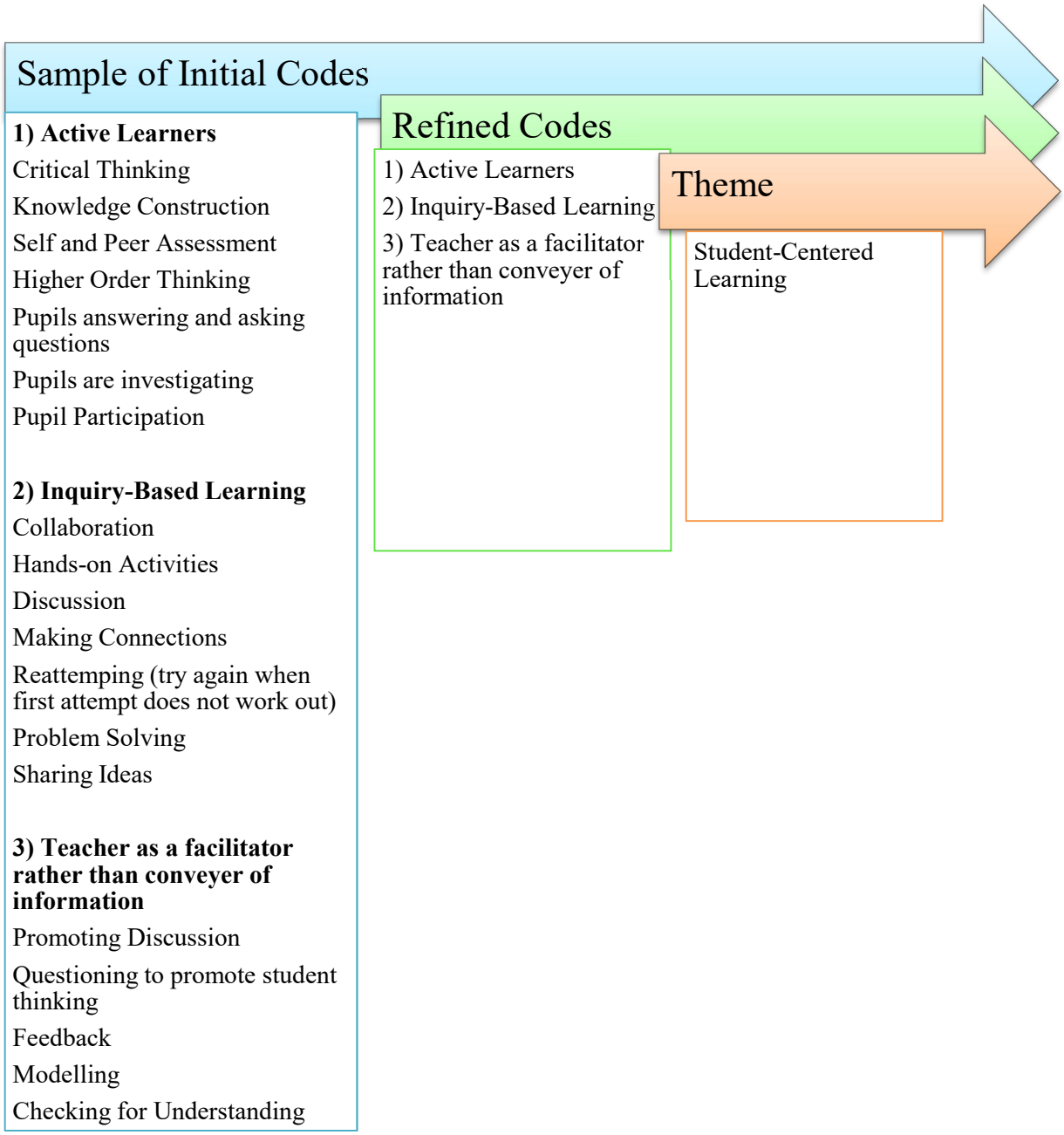

Figure 4.4 The initial and refined codes which led me to the construction of the theme 'Student-Centred Learning'

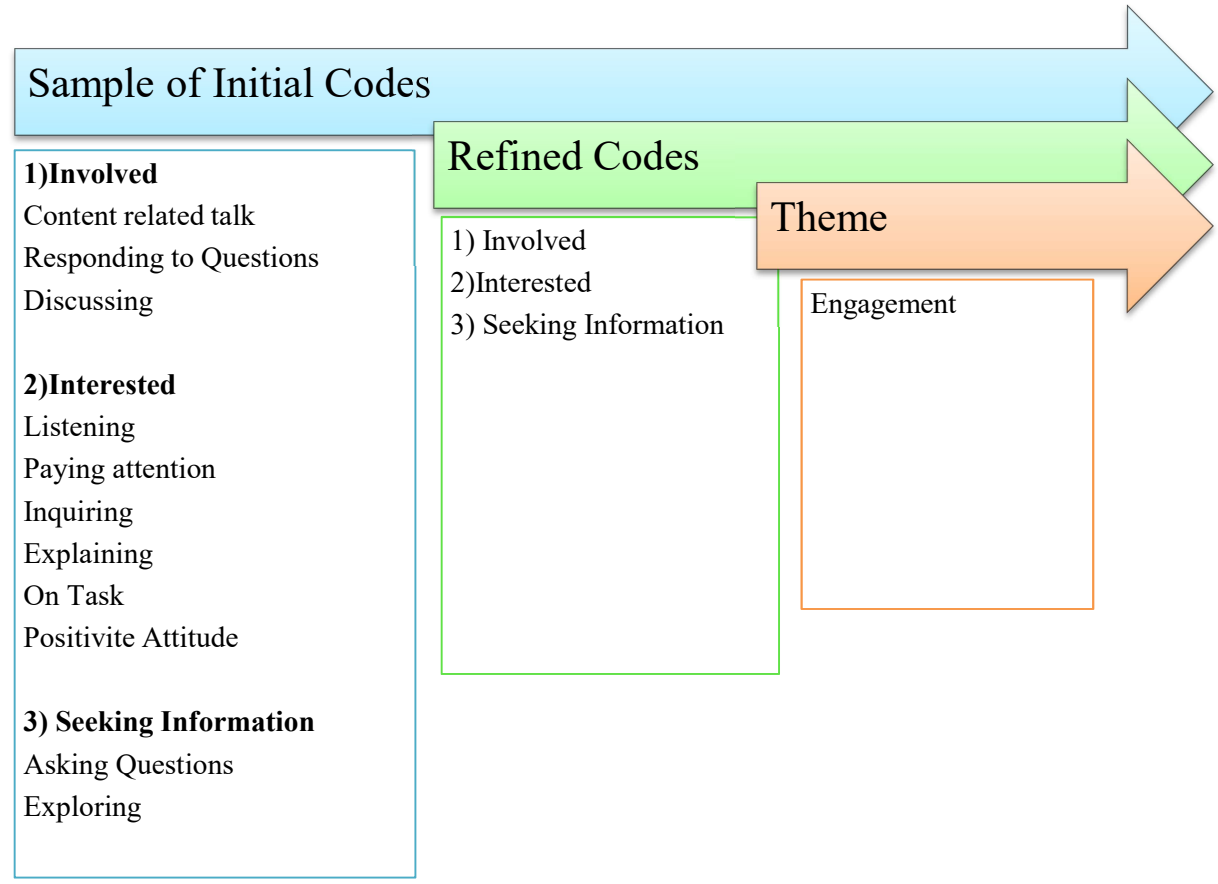

Figure 4.5 The codes which led to the theme of 'Engagement'

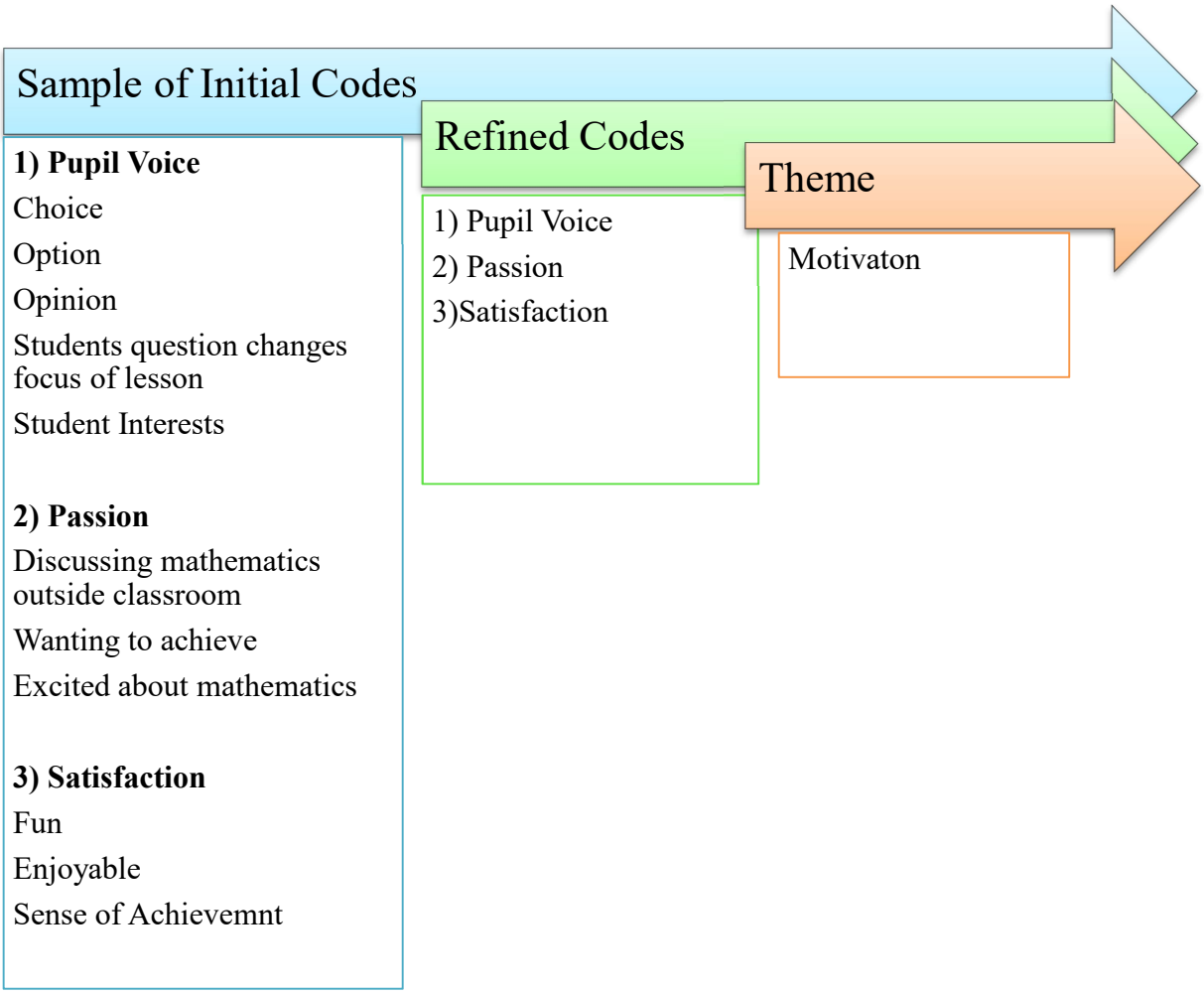

Figure 4.6 A list of initial and refined codes for the construction of the theme of 'Motivation'

Theme 1 Student-Centred Learning

One of the goals of this action research study was to answer the proposed research question, which asked: How does enacting rich mathematical teaching and learning affect pupils' motivation to engage in mathematics lessons? However, it is important to remember that teacher change is a desired outcome of action research and thus another one of the goals of this study was to make changes in order to improve my own classroom practice. The critical question that action researchers pose to themselves is, "How do I improve what I am doing?" (Whitehead, 1993). The first

theme of ‘Student-Centred Learning’ highlighted to me that I have made changes for the better and thus have improved my classroom practice. The codes that emerged from analysing the different data sets enable me to say that I have moved away from a traditional, didactic style of teaching and towards a more student-centred approach. Slavich and Zimbardo (2012) refer to the student-centred approach as a process which put pupils at the centre of inquiry and problem solving, supporting these pupils in generating their own strategies to solve cognitively challenging tasks and in constructing their own understanding of mathematical concepts. In order for this process to work effectively, it is necessary for teachers to make a meaningful contribution to mathematics lessons, as the pupils will still require some level of background knowledge and scaffolding. I used Grossman’s Core Practices as a vehicle to enact student-centred learning in my classroom. These high leverage practices include strategies such as leading discussions, explaining and modelling content, eliciting and interpreting student thinking, checking for student understanding, giving feedback. I also used Gladis Kersaint’s (2019) ‘100 Questions that Promote Mathematical Discourse’ in order to help me ask effective questions that would elicit student thinking and encourage discussion amongst pupils. When moving in the direction of a more student-centred approach to teaching I found myself struggling to release some of the control to the pupils. However, I feel the initial codes and being able to refine those into the theme of student-centred learning implies to me that I successfully moved in the direction of enacting a student-centred approach to teaching. This conclusion is backed up by the scores from the Learner Centred Rubric.

Theme 2 Engagement

Engagement, while emerging as a separate theme in my data is closely linked to student-centred instructional practices. As previously mentioned, Talbert, Hofkens and Wang (2018) discuss the four components of engagement: behavioural, emotional, cognitive, and social. In terms of mathematics, they considered behavioural engagement as referring to involvement and the presence of positive behaviour. The codes which emerged from the data showed an increase in the involvement level of the children when engaging with the student-centred approach while the results from the observation checklists showed that the learner centred process resulted in a higher presence of positive behaviours and a decrease in negative behaviours, thus behavioural engagement was evident.

Talbert, Hofkens and Wang (2018) describe emotional engagement as the positive interaction with teachers, peers and classroom activities, as well as the pupils' emotional relationship with the learning material. Again, this is directly linked to the change in teaching practices that I enacted in my classroom. By using a more student-centred approach, the children had a more positive experience of mathematics as they enjoyed collaborating with their peers and with me, the teacher, in order to construct knowledge. They were more willing to participate in learning activities and achieved a sense of success more often. This enhanced sense of enjoyment was reiterated in the results from the student rating scales, as seen in Figure 4.2 above. This ensured their emotional engagement needs were met.

Cognitive engagement denotes the pupils' self-regulated learning, use of deep strategies, and ability to use the appropriate strategies to comprehend complex ideas in mathematics. This again was a crucial element of the student-centred process. As I moved away from the traditional style of teaching, pupils were no longer passive

learners who received knowledge but rather critical thinkers who constructed knowledge and understanding. It was also evident as the pupils took ownership of their own learning by asking questions, exploring and engaging in discussion in order to solve problems and in the fact that pupils were looking forward to mathematics lessons.

Lastly, social engagement reflects the quality of pupils' social relationships and their willingness to form and maintain relationships while learning. The children's social engagement needs were met as they engaged in collaborative, inquiry-based learning where they worked together to discuss mathematics, solve problems, enhance understanding etc.

As is evident from the previous points, there is a strong connection and link between engagement and the student-centred teaching approach.

Questioning

Another finding that emerged from this research was that prior to this study I was of the opinion that I asked open-ended and encouraging questions that provided an environment in which pupils were happy to share their ideas and thoughts. However, on reflection, I quickly noted that I was actually asking closed questions in my teaching that required a simple yes or no answer. These questions were basic and did not allow me to check for pupils' understanding, or to elicit student thinking. Changing to asking more open ended questions when teaching enabled me to promote mathematical discourse and allowed me to check for pupil understanding and to highlighted pupils' misconceptions. It also helped to engage the children more as they were discussing their thinking and engaging in mathematical discourse. This was a simple concept, yet I found it difficult to enact. In order to help me change to

using more open ended questions in my teaching, I used Gladis Kersaint's (2019) '100 questions that Promote Mathematical Discourse'. However, when I began using them I tried to use the whole list in a lesson. As a result, I was asking the pupils so many questions and I found this very overwhelming, as did the pupils. Thus, I was not getting the most benefit out of the list as I possibly could have been, so instead I started to anticipate what questions might be required during a lesson and I would use these key questions instead of the list as a whole. This is something I will continue to do as I move forward because although, this was much more manageable for me, asking these open-ended questions was still a challenge as it did not come naturally to me and so it was necessary for me to have the questions written down and to keep referring back to them. I would recommend for others who intend on using these questions to use a similar approach in order to make it more manageable and effective.

Theme 3 Motivation

Motivation is linked to both student-centred learning as 'students report higher levels of intrinsic motivation in academic work when their teachers are using student-centred instructional practices' (Talbert, Hofkens and Wang, 2018: 328) and to engagement as 'the relationship between engagement and motivation is a two way street; improve one and you also improve the other' (Burton, 2013: 1). An increase in pupil motivation was evident from the data collected as the children began talking about their mathematics lessons while out on the school yard. These children also became excited about maths and they looked forward to the mathematics lessons as they often asked, 'Is it nearly maths time?' One of the factors which I feel increased pupil motivation was the sense of achievement that each pupil was now experiencing, particularly the lower performing children. Where they used to sit

staring blankly at a page in a textbook unable to complete the tasks successfully, they were now involved in discussions and inquiry-based learning and were achieving in mathematics. Other factors included: 1) enjoyable learning experiences: an increase in enjoyment is also linked to an increase in motivation as pupils want to participate in the activities because they find them interesting and fun; 2) pupil voice: the children were now being given choices and asked for their opinions so they had some responsibility over their learning; and 3) pupil interests: trying to incorporate pupils' interests into mathematics lessons was also a key factor in increasing motivation. Overall, I feel the move towards student-centred teaching had a key role to play in increasing motivation as pupils now had a sense of responsibility over their own learning as they became critical thinkers who were constructing the knowledge themselves rather than being passive recipients who received the knowledge from the teacher. This sense of involvement appealed to the pupils and, thus, motivation increased.

Intervention.

The data I collected would suggest that the intervention was successful, in that it brought my teaching closer in line to the values I hold and it also increased pupils' motivation to engage in mathematics. I observed an increase in engagement from almost all of the children who participated in the research, with the highest increase coming from the lower performing children. These children were now willing to participate in mathematics lessons, were involved in tasks and activities and were achieving a sense of success in mathematics. They were now thoroughly enjoying mathematics class, which was reflected in the discussions I had with these children and in their student rating scales. It was very rewarding to see these children no longer being frustrated and tormented when trying to do mathematics activities as a

result of a carefully crafted plan that changed the look, sound and feel of our mathematics classroom. I planned this intervention as I envisioned a transformation for my classroom and my teaching practices and seeing this transformation unfold was a real thrill for me. Silence turned into discussion and debate, and the pupils' dependence on me, the teacher, transformed into independence.

Although the intervention was successful for most children in the class, when reflecting on the data I had collected I became aware that one child did in fact show a decrease in his level of engagement in and enjoyment of mathematics lessons. For the purpose of discussion, I will refer to this child as Child 15. Figure 4.7, below, shows the results from the child's rating scales over the time of the intervention and Figure 4.8 shows the data collected using the observation checklists for the same period. In Figure 4.7, you will notice that the child rated the lessons during cycle 2 as 'awful' and 'not very good' and at no point during this research cycle did he choose anything other than these two ratings. This suggested that the child was not enjoying these mathematics lessons. This is also reflected in his engagement levels, as seen in Figure 4.8. Figure 4.8 identifies the child's positive behaviours in green and negative behaviours in red. Over the course of the intervention, there was a significant decrease in the child's positive engagement behaviours and a substantial rise in the child's negative engagement behaviours. This suggested to me that the child was not engaging well with the mathematics lessons. Again, the data on the left hand side of the line is the data that was collected in Week 1, which was pre-intervention and the data on the right hand side of the line is the data collected in research cycle two, when the intervention was being implemented.

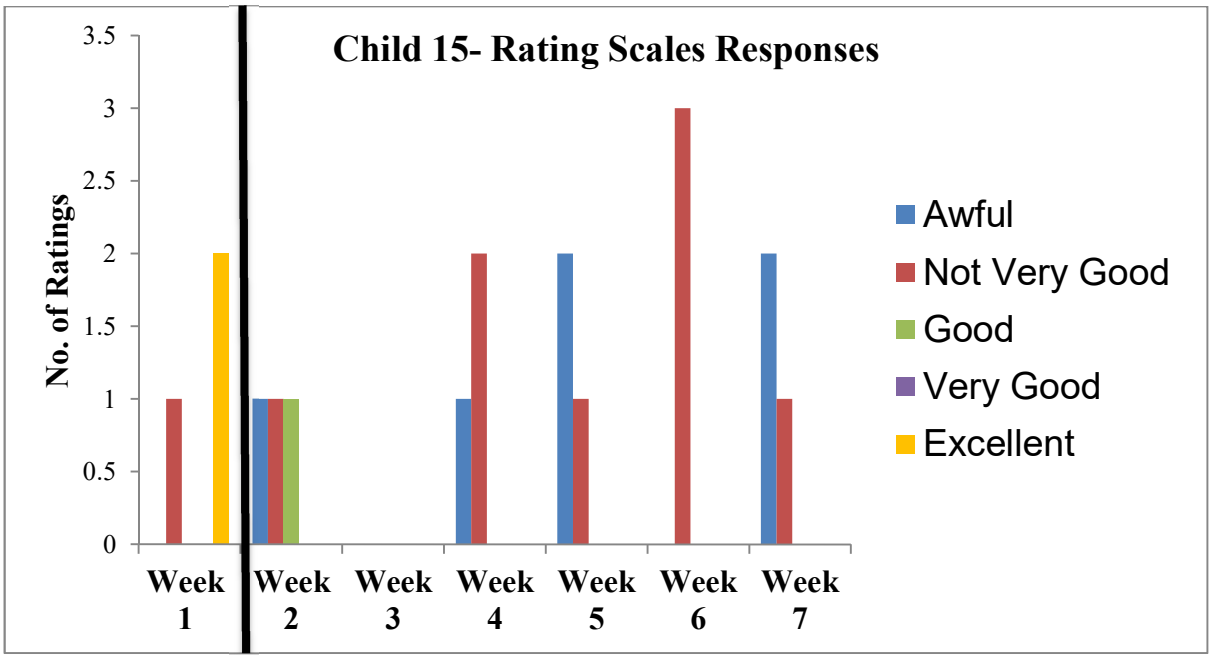

Figure 4.7 Data collected from rating scales for Child 15.

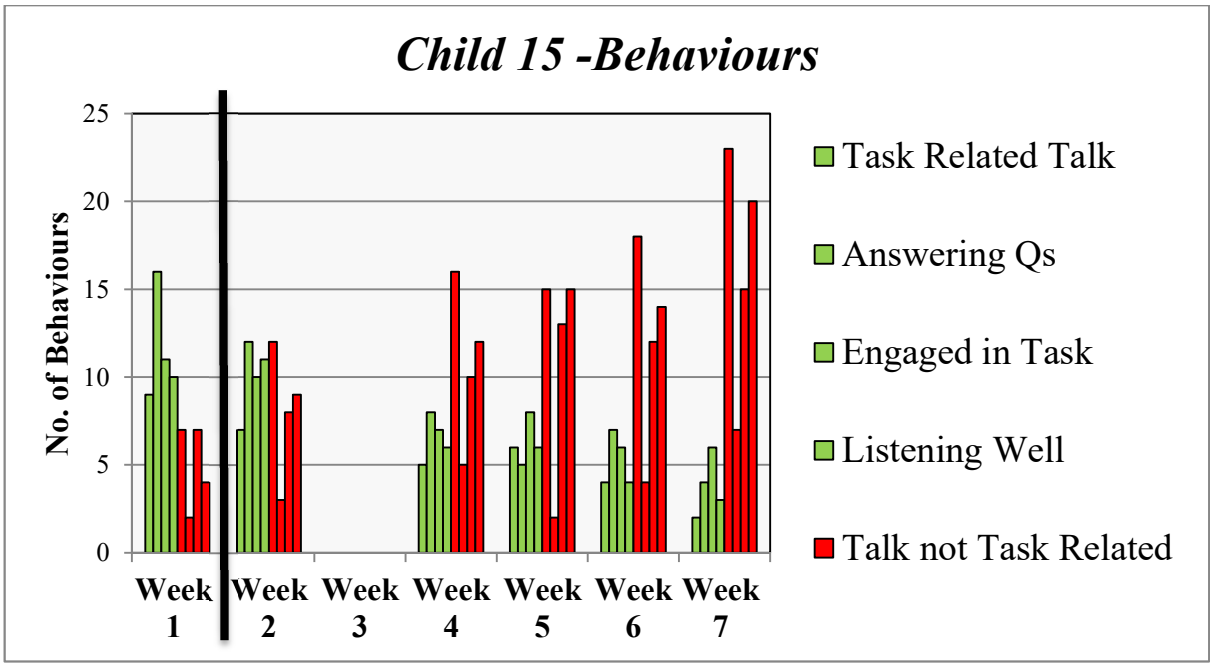

Figure 4.8 Results from behaviour checklists for child 15.

There was also evidence of a decrease in enjoyment and engagement for Child 15 in the qualitative data. The following quotes have been taken from the qualitative data:

- 'He didn't like working with his group'

- ‘Child 15 asked “When can we go back to doing normal maths in our books?”’
- ‘Child 15 was very distracted during today’s maths lesson and did not engage well, particularly in the group work’
- ‘Child 15 asked “Can I do this on my own instead of with her?” while refusing to work alongside his partner’
- ‘Child 15 stated that he didn’t want to play the boring game and that he doesn’t like maths anymore’

These quotes support the evidence collected using the quantitative data collection methods. This finding contradicts much of the more recent literature in this area, which suggests that a pupil’s opinion of group work depends on their past experiences and their expectations of their teacher. Walker and Shore completed a study on whether or not high-performance pupils prefer working alone and they note that ‘in general, high-performing (HP) students did not prefer to work alone’ (Walker and Shore, 2015: 85).

There are a number of reasons in the literature to suggest why child 15 might not want to participate. First, child 15 is higher ability. This was evident to me, the class teacher, from his answers in class, his performance in teacher-designated tasks, from observations I had made, and from his performance in class tests etc. He also received a STEN of 10, the highest possible score, in both a standardised maths test and standardised English test when they were administered to him in the early months of first class, despite the fact that these tests are not due to be administered to first class children until the end of their year in first class. The student-centre learning approach requires children to work together in groups very regularly and while recent research suggests that higher ability pupils do not prefer to work alone,

this is dependent on a number of factors. Higher-ability pupils sometimes suggest a preference for working along because of the 'free-rider effect, as coined by Orbell and Dawes (1981), wherein one or more members of a group do not contribute the same amount of work or effort as other members of the group' (Cera Guy, Williams and Shore, 2019: 177). Another reason for the lack of participation may be child's past experience of group work. Cera Guy, Williams and Shore (2019), noted this and discussed how a pupil's past experience of group work and whether they feel their ideas and opinions were accepted or rejected in previous situations influences the individual's feelings towards group work. French, Walker and Shore (2011) discuss how resistance to group work can also be depended on how supported the pupil feels in their learning by their teacher and peers. Child 15 may simply just be unhappy with the thoughts of change, as Weimer (2013) notes it is human nature to be uncomfortable with change. Weimer (2013) also discusses four other possible reasons why students might be less enthusiastic and even rebellious when presented with student-centred teaching. Firstly, student-centred approaches require more work. You are no longer providing students with the knowledge they need but instead are asking them to construct knowledge for themselves. This requires more mental effort on behalf of the child. Secondly, Weimer (2013) describes how the student-centre approach is threatening for some children. In this type of classroom 'the details about: what to do, what the "right answer" is, and who is responsible for what is suddenly less clear than they what they have come to expect' (Weimer, 2013: 4) with the traditional style of teaching. This new experience can be daunting and can cause children to become quiet anxious as they now have a fear of failure in this unfamiliar environment. Another reason which Weimer (2013) presents is the idea that student-centred learning involves losses. The student-centred approach develops

children's ability to think critically and to learn independently as the responsibility for learning is now placed on the pupil. A pupil may experience a sense of loss when a student realises that they are making a move towards independently making decisions. The last reason that Weimer (2013) puts forward is the idea that a student is not intellectually ready to become the independent learner that is required when using the student-centred approach. However, I feel this is the least convincing explanation in the case of child 15.

I am unsure as to which, if any, of these reasons is relative to Child 15. It may have been linked to his past experience of group work and whether or not he previously experienced the 'free-rider' effect or whether he felt supported. It may also simply be the fact that there was a change in routine and that he was uncomfortable with this change, despite this being clearly explained to him prior to the intervention occurring. Other reasons might be that he came to the realisation that there was more work required on his part, a fear of failure, or the idea of experiencing loss when moving towards independent learning. There is no evidence in the dataset that clearly explains his lack of engagement and it is not typical of his daily involvement in school. Child 15's lack of participation is something I would like to speak with the child in relation to and to research further in order to get further clarity around why this occurred and how I can change my teaching practice to try to minimise the likelihood of this occurring again in my future teaching. For now, having consulted some of the literature, I will implement changes and adjustments that may help me to avoid this same result as I continue to research and seek solutions for this child's lack of participation in order to try to avoid this in my student-centred classroom going forward. These changes are outlined in chapter five in the section entitles 'Suggestions for Future Research'.

Inclusion

I have spent considerable time discussing the impact of the intervention on one pupil, child 15. The reason I have chosen to focus on this child is because of my value of inclusion. As discussed in chapter two ‘an inclusive classroom as one where learning ‘can be accessed by all students in the class, regardless of prior learning history, demographic/social identities, or belief in their ability to succeed’ (Penner, 2018: 69). It involves removing barriers so that each learner will be enabled to achieve the maximum benefit from his/her schooling. Inclusion is a process which involves addressing and responding to the diversity of needs of all learners and enabling pupils to feel respected, valued, stimulated and supported in their environment, as I value inclusion and strive to ensure all pupils in my class are learning to the best of their ability. Implementing a more student-centred methodology in my classroom has allowed me to live closer to my value of inclusion as more pupils are now accessing learning in a way that is suited to their needs. However, I cannot say that I am fully living to my value of inclusion until every child is learning to the best of their ability, including child 15. Thus, I spent a considerable amount of time researching and seeking answers for the lack of participation from child 15 in order to try to overcome this problem and to enable me to help child 15, and anyone else in a similar situation in future, to access the learning, allowing me to fully live up to my value of inclusion.

Conclusion

Chapter 4 has presented the analysis of the quantitative and qualitative data collected to address the effect of enacting rich mathematical teaching and learning on pupils’ motivation to engage. The data collected answered the following research questions:

How does enacting rich mathematical teaching and learning affect pupils' motivation to engage in mathematics lessons?

The data suggested that enacting rich mathematical teaching and engaging pupils in rich mathematical learning enhanced the enjoyment of maths lessons for most children and thus increased their motivation to engage. This had a positive effect on the pupils' attitude towards math. The data also suggested that giving pupils a choice and a platform to voice their opinions and ideas has a positive effect on their motivation to engage in math lessons, leaving them with a more positive attitude toward math after participating in the intervention.

Chapter Five: Implications and Conclusions

This study was designed to explore the effect of rich mathematical teaching and learning on pupils' motivation to engage in mathematics. I employed action research methods of data collection and analysis in order to capture the nature of changes that were made to my teaching practice. This chapter will provide a summary of the findings of my research study, discuss the implications of this research, and conclude with suggestions for future practice.

A Summary of the Findings

This research revealed that enacting a student-centred approach to teaching, as opposed to a didactic style of teaching, can increase pupils' engagement levels, as well as their motivation. Enacting a student-centred approach, whereby the pupils were constructing their own knowledge, as opposed to being passive recipients of knowledge, resulted in further engagement in mathematics from the children. The student-centred approach appealed to the four components of engagement: behavioural, emotional, cognitive and social and thus was successful in increasing engagement.

Implementing the student-teacher approach led to an increase in pupil motivation. This was evident when the children began talking about their mathematics lessons while out on the school yard. Indeed, they were excited about maths and looked forward to the mathematics lessons. Pupils felt an increased sense of achievement, as they were now involved in discussions and inquiry-based learning and, as a result, were able to achieve in maths, instead of being frustrated and staring at a textbook page. Overall, the move towards student-centred teaching had a key role to play in increasing motivation, as pupils now had a sense of responsibility over their own learning, becoming critical thinkers who were involved in constructing the

knowledge themselves rather than passive recipients who received the knowledge from the teacher. As this sense of involvement appealed to the pupils, motivation increased.

A key learning point for me was that the teacher's role in the classroom is central to pupils' learning and is absolutely essential to effectively implementing the student-centred approach. The teacher must effectively use the high leverage practices I have previously discussed in order to maximise children's learning.

Additionally, I learned that change is gradual and challenging due to the complexities of teaching in the classroom context and that, in order to make changes, one must first reflect on their own practice and continue this reflection as an ongoing process. Engaging in reflection enabled me to realise that I was impeding pupil engagement due to the idea of 'teacher lust', whereby I would act in ways that prevented children from thinking about or engaging in mathematics. This prevented the pupils from becoming critical thinkers, as they weren't given the opportunity to engage in mathematical discourse and to solve problems. Although I realised I was doing this and I was determined to change, moving away from this teacher-centred approach was harder than I had originally expected and I still found myself doing this even during research cycle 2, where I was implementing the student-centred approach. However, the fact that I am now aware of what I was doing means I am now conscious of it and will continue to make an effort to change this.

I also realised that providing the children with the content in a traditional, lecture style approach was not living up to my value of developing critical thinkers and that if I wanted my children to become critical thinkers I must allow them to have an active part in the construction of their own knowledge. I now know that I must act as

a facilitator in the classroom who elicits student thinking, promotes mathematical discourses, gives feedback, checks for understanding, questions, models and explains, leads discussions and lets children work together to discover the mathematics instead of them relying on me to give them the knowledge. My goal of wanting my pupils to learn the content by giving them the information and expecting them to learn it must shift to one in which I strive to help them to learn the content by allowing them the freedom to understand the mathematics and discover it together. This change is necessary for me in order to improve my teaching practices.

Impact of Action Research

In this section I outline the implications of this study for my practice, for teachers' practices and for researchers. In terms of my practice, I will discuss how this study serves me as professional development, how reflection affected me, how I learned from my critical friend, and how I changed my practice through the process of action research. I will also discuss how this study can serve other teachers and other researchers too.

What Were the Impacts of the Study on my Practice?

I feel that the data I have collected in order to answer my research question will prove to be very valuable to me in future practice. It has enabled me to enhance my teaching practice, as it allowed me to address the problems I identified in my teaching. Previously, my teaching style was contrary to the values I hold and I was experiencing Lortie 's (1975) 'Apprenticeship of Observation'. I had forgot about what I truly valued and instead began teaching in the way in which I was taught, which consisted of mainly textbook work. Completing this action research helped me to revert back to a style of teaching where I was living closely to my values. It also helped me to determine the true meaning of what my values were and to redefine

these values for myself. When beginning the research I stated that I valued student-centred teaching and developing children as critical thinkers. Starting out I believed that, in order to teach according to these two values I should be solely using child-led activities and, in order to be an effective teacher, the children should be constructing all of the knowledge themselves. As such, I should only have a role as a facilitator of these activities, someone who would only intervene when absolutely necessary. However, having completed this research I discovered that effective teaching encompasses much more than this and that it is not possible for everything to be child-led. Instead, the teacher must implement the High Leverage Practices, as discussed previously, in their teaching, whereby the teacher is modelling, demonstrating, explaining, facilitating discussion and questioning, checking for student understanding during and after a lesson and providing feedback to the children. These practices act as a vehicle for implementing rich mathematical teaching and learning using a student-centred approach which enhances pupils' motivation to engage. Thus, this is something I would implement across all subject areas in my future teaching. I would also have to make a conscious effort to include necessary steps in relation to engaging higher ability pupils in group work in my future teaching practices.

This study enabled me to see the true power and necessity of reflection. I never used to take time to formally sit and reflect about the lessons I taught each day; how it went, what went well, what did not go well, what was surprising etc. Having dedicated time to do this reflection helped me to get to know my pupils as learners and to make the necessary adjustments and changes to follow up lessons. It also helped me to acknowledge the challenges I faced that day and to think about how I would overcome those challenges the next day. Taking this time to reflect on the

lesson daily provided me with more insight into whether or not my pupils comprehended the material and what it was I could change to allow them to better understand the content. Reflection also afforded me the opportunity to challenge my own teaching. It was through reflection I realised that I was not living up to the values I hold and although this brought about feelings of vulnerability and a sense of being uncomfortable it helped me to grow professionally as a teacher as I confronted myself and changed from a traditional teacher to one who enacted student-centred practices. This purposeful reflection and analysis challenged me while helping me to grow professionally in a way that was meaningful in my classroom.

In addition, working with my colleague, in the form of a critical friend, has helped me to develop the skills necessary for a collaborative process. These skills will be useful to me as I continue to engage in collaborative processes in our school community be it with pupils, colleagues, management, parents etc.

Additionally, I was not previously asking open-ended and encouraging questions that provided an environment in which pupils were happy to share their ideas and thoughts. Instead, I was actually asking very closed questions that required a simple yes or no answer. These questions were basic and did not allow me to check for student's understanding, eliciting student thinking etc. Changing to more open ended questions which promoted mathematical discourse and allowed me to check for pupil understanding and to highlighted pupils' misconceptions is a concept which I will carry forward in my practice.

Challenges after this study are still present. I still find that my teacher lust can interrupt and diminish opportunities for pupils to explain their understanding to others. It is difficult to change a habit like this, but I endeavour to continue to

improve this. Changing my mind set to one where I give some of the control to the pupils and allow them to be active learners who construct knowledge is not something that comes naturally to me, instead I am more comfortable with the routine of the traditional style of teaching and thus I sometimes find myself reverting back to these ways. However, this study has shown me different approaches and ways of teaching that I previously was unaware of in my traditional classroom and the benefits which arise as a result of these teaching methodologies. One aspect I find significant from this study is the ability of my pupils to collaboratively work together to solve mathematics problems and to learn mathematics concepts. I was pleasantly surprised with how my pupils struggled together, learned together, and found success together. Change takes time, and only through dedication will change actually take place in my classroom and remain in place.

How Can This Study Serve Other Teachers?

Obviously, I benefited a lot as both a teacher and researcher from this study. Personally, I learned to make sense of problems in my classroom and to solve them by continuously working to improve using action research methodologies. An important aspect of action research is the dissemination of the research. This dissertation serves as one form of dissemination for my study. Additionally, sharing this research, in the ways in which I have previously discussed, will help other teachers learn to enact rich mathematical teaching and learning.

Rich mathematical teaching involves a student-centred approach which is accompanied by the core practices, which I have previously discussed in chapter two. Teachers are constantly being reminded of the need for student-centred teaching approaches and there is a lot of research available to teachers on student-centred learning. However, there is not much awareness around the idea of core practices and

thus, I hope this study will make teachers more aware of the idea of core practices as I believe that every school should adopt some of the core practices which I have discussed in chapter two. Practicing teachers should engage in a process of continuing professional development whereby all teachers are trained in a similar manner in order to be able to use these core practices effectively in classrooms nationwide. I would agree with Grossman (2009) who recommends that learning be organised around a set of core practices and that these core practices should be agreed on nationwide, not only by teacher educators but also supervisors and co-operating teachers also. This will promote a clear vision for teacher education and ensures that teachers nationwide are using the same set of core practices in their teaching. Additionally, I hope to help them to see the benefit student-centred learning can have in increasing pupil engagement and motivation. I am just one teacher; my experience is unique to me. It would be beneficial to have another teacher complete a similar study to compare their experience with my own.

As a concrete outcome of this action research study, I propose the following questions, which other teachers should consider when planning effective maths lessons:

- What does inquiry-based learning really look like?
- How can I ensure the engagement of all pupils in group work?
- How can I develop critical thinkers in my primary maths classroom?
- How many steps do I need to take to ensure pupils do not experience the ‘free rider’ effect when working in groups?

How Can This Study Serve Researchers?

This study also has implications for mathematics education research. Acting as both the researcher and the teacher at the same time provided an opportunity for me to bridge the gap between research and practice. Being an insider in my own classroom presented a unique opportunity that most researchers do not have. An action research study, similar to this one, could highlight the challenges that classroom teachers face when it comes to implementing research in their classrooms due to the many complexities of the classroom and school context. They could also witness that, even when curriculum is written with particular intentions, the enactment of the teacher has direct impact on whether that intention occurs in the classroom.

Challenges

Conducting self-study action research presents many challenges for the researcher. Firstly, the participant is acting as both the researcher and the participant and so it is necessary to ensure that the research is not biased. In order to try to show trustworthiness and to minimise bias in my research, as mentioned previously in chapter three, I used a range of both qualitative and quantitative data collection techniques. Using multiple sources and a mixture of both qualitative and quantitative data allowed me to triangulate the data. Triangulation adds to the richness of your research because the changes you have made are acknowledged and recognised by more than one person and thus the research is less likely to be biased.

Another struggle related to questioning which I encountered during the course of this research study was the move away from the teacher centred approach and towards the more student-centred approach. With traditional, teacher-centred teaching I answered the questions while the student-centred approach saw me having to either redirect those questions to other members of the class or posing another question in

response to the original in order to elicit student thinking. This struggle was linked to Mary Boole's construct of teacher lust, which was another struggle I encountered. Teacher lust is referred to by Tyminski (2009) as an internal impulse to act in a way that prevents pupils thinking about or engaging in mathematics for themselves. Tyminski (2009) suggested a reason for this stating that 'teachers, however, harbor a natural desire to impose their own understandings upon their students, even though this approach may be in opposition to their education goals' (Tyminski, 2009: 296). Teacher lust has the potential to hinder pupil learning because teachers give into the urge to tell students exactly what to do. Without realising, I was giving pupils the answers to questions straight away, almost before they had even had a chance to finish the question. This did not offer the pupils a chance to reflect upon or respond to the question and thus did not require pupils to think for themselves. This allowed pupils to fall into a bad habit of asking me the question the very minute they encountered a problem because they knew I would give them the answer and they would not have to work for it. This prevented the pupils from becoming critical thinkers as they weren't given the opportunity to engage in mathematical discourse and to solve problems. Although I realised I was doing this and I was determined to change, moving away from this teacher-centred approach was harder than I had originally expected. Cady (2006) also experienced difficulty with this, describing the struggle she encountered in providing adequate wait time for pupils to respond. She notes how she was often tempted 'to rephrase the question or ask another leading question to break the silence' (Cady, 2006: 462) and that she had to resort to methods such as silently counting to twenty, sitting down and forcing herself to be patient and allow students time to think.

Tyminski (2009) proposed two forms of teacher lust: enacted and experienced. 'Enacted teacher lust is an observable teacher action that may remove an opportunity for students to think about or engage in mathematics for themselves' (Tyminski, 2009: 307). While experienced teacher lust refers to 'the impulse to act in the manner described above' (Tyminski, 2009: 307). Experienced teacher lust often happens unconsciously, as teachers proceed into a state of enacted teacher lust, completely unaware of this tendency. During this research study, I considered Boole's construct of teacher lust and I tried to hold back any urge to immediately answer pupils' questions and to help them straight away. Instead, I tried to offer pupils the opportunity to reflect upon or respond to the question, allowing them time to think for themselves and to engage in mathematical discourse.

Facilitating the student-centred approach in my classroom turned out to be a struggle also, particularly at the beginning. Like Cady (2006) and Umbeck (2011), as well as other researchers, I, too, struggled with the transition from a teacher-centred to a student-centred classroom. My pupils originally found it difficult to work together in groups and to talk together and listen to each other. It was as if they were afraid to talk together for fear of getting in trouble, despite me encouraging collaborative talk and trying to create a positive environment. Cady (2006) also mentions a possible reasoning for this may be because pupils are afraid of being incorrect. However, as they became comfortable engaging in mathematical discourse and as their confidence increased their fear of being wrong decreased significantly. In addition, when I began using the student-centred approach I experienced difficulty similar to that of Cady (2006) in that 'many students seemed to feel that their response was incorrect whenever I asked for an explanation' (Cady, 2006: 461). However, with reassurance, the pupils soon came to realise that I was just curious about their thinking and was

looking to engage them in mathematical discourse. Additionally, similar to Umbeck (2011), the change in classroom norms was originally a struggle for the pupils as they tried to get used to the new routines. Umbeck (2011) believes that this initial struggle was a result of the different view of mathematics the children were experiencing in comparison to the years of traditional mathematics experiences they were previously exposed to. She notes how 'it took time to model new ways of participating and to begin the process of renegotiating classroom norms with the students' (Umbeck, 2011: 91). I experienced a similar situation in my classroom as I too found it took time for me to model the new teaching approach and for the students to process this new approach. Also similar to Umbeck, I too found that 'groups were initially unproductive, did not know where to begin, and were apprehensive about the perceived lack of guidance they were receiving' (Umbeck, 2011: 91). As a result, I found the group work to be ineffective at the start, as pupils wanted me to give them the knowledge and to answer the questions similar to the way it had been before because even though 'many students had experienced only limited success in previous mathematics classes, they were more comfortable with recognizable routines and looked to me to maintain them' (Umbeck, 2011: 91). After a while, pupils became comfortable with the new approach and they started to experience the benefits associated with enacting a more student-centred teaching approach. This can be seen by the increase in student enjoyment and engagement over the course of the intervention, from observational notes, notes from my critical friend and it was also reflected in quotes from the students which were documented in my reflective journal and also in the notes from student-teacher conferences. The following are some examples:

> *Child 20 stated that at first the new way of doing maths was weird but now that we have practiced it it's actually really fun.* (Kealy, 2020)
>
> *The children seem to be coming to terms with the new routine. It was difficult to engage them in conversation last week as they seemed very nervous and were very embarrassed when they got something wrong. This week there seems to be a positive turn and children are starting to open up and to share their ideas and answers.* (Kealy, 2020)
>
> *'Child 18 noted how they didn't realise maths could be learned in a fun way like this'* (Kealy, 2020)
>
> *Child 21 casually remarked in class today that they like sharing their ideas with the class and when everyone works it out together it is easier to understand.* (Kealy, 2020)
>
> *The children seemed much more comfortable with the teacher's new teaching style. They were engaging in mathematical talk and no longer seemed afraid to share their opinion or to ask a question. This talk was focused with the children only straying off topic a few times and even at that they were quick to return to focus when the teacher called upon them.* (Critical Friend, 2020)

Finally, as I mentioned previously, another challenge I encountered was the idea of releasing some control of the classroom to the pupils, as I found myself missing the comfortable routine that accompanied the teacher-centred approach. However, I was determined to live more closely to my values and to make changes to my teaching practice in order to improve it and thus I proceeded with the changes despite the struggle.

While I knew I wanted to change my practice in order to live more closely to my values, changing my practice was not easy. There were many times where I succumbed to the temptation of simply giving students the information. However, as I gained more confidence and became comfortable with my new teaching approach, I

became more determined to enable students to construct knowledge for themselves and, while there were still days when I reverted back to traditional teaching and direct instruction, the amount of these days were very limited and, used sparingly, were effective.

Limitations

Every study of course has its own limitations. One limitation when conducting research and analysing data is the idea of participant bias. Farnsworth (2019) explains how this occurs when children can change their behaviours or answers depending on what they believe the teacher researcher is looking for. This occurred early on in my data collection as one of the children discussed how 'she didn't want to circle a sad face for teacher because teacher was really nice' (Kealy, 2020). This child was answering questions and completing rating scales based on how she wanted me to feel and what she thought I, as her teacher and researcher, wanted to see in her answers. In order to overcome participant bias, I needed to remind the children in my class about confidentiality and also the importance of telling the truth in the rating scales. I ensured them that I would not be upset by the answers they gave and in fact if they were telling the truth they were far more helpful to me.

Another limitation is the idea that self-study action research is completed in the classroom and inherent in classroom research are the inevitable, and often unanticipated, challenges experienced by researchers. As Baker and Lee (2011) highlight, a researcher's viewpoint can be distorted by either premature judgments or personal biases. Premature judgments can arise from assumptions made based on prior research and 'personal biases can form based on the interests or values held by observers' (Baker and Lee, 2011: 1437), thus presenting a dilemma for a researcher conducting research in their own classroom. I presented with my own premature

judgements prior to conducting this study. Despite valuing inclusion and student-centred education and its ability to develop critical thinkers, I had convinced myself that the pupils in my class were too young and thus, they would not be able to construct knowledge for themselves. I also hesitated in handing some of the control over to the pupils, as I believed that the groups would be unable to focus and that when given permission to talk together the children would take this opportunity to discuss anything other than maths.

Another major limitation of self-study action research is the fact that I was surrounded by the environment and participants in my research on a daily basis. This made it more difficult for me to notice subtle changes that occurred as I became accustomed to the changing attitudes and behaviours of the children. In order to overcome this, I was in constant communication with my critical friend who was not used to the environment and thus was more aware of the changes that were being made. My reflective journal was also helpful in trying to minimise this problem.

Another limitation is the fact that classrooms are highly unpredictable places and there are often events and situations which arise that distract you and the participants from conducting and partaking in the research, such as a visitor calling to the classroom, the fire alarm activating, a specific child having an outburst and requiring the full attention of the teacher, and so forth. These are just other factors which contribute to the challenge and the messiness of conducting self-study action research in your own classroom.

Suggestions for Future Practice and Next Steps in Action Research

In moving forward with this research, I will continue to allow time for purposeful reflection in order to continue to improve my teaching practice. Based on the results

of the study, and in consultation with the literature, there are several recommendations which I will implement in my future practice

In order to overcome the 'free-rider' effect, which I discussed in chapter four, I will implement 'classroom and evaluative structures that build and reward pupils making their best contributions and hold group members accountable' (Cera Guy, Williams and Shore, 2019: 183). I will implement classroom routines that reward the effort made by each individual pupil in a group and I will ensure to hold everyone in the group accountable. To ensure this is effective, pupils will be regularly reminded of my expectations of them during group work and I will give them opportunities to reflect on the group work to consider if they felt these expectations were met.

I will continue to circulate between groups as I had been doing, but in future practice I will be particularly conscious of uneven contributions and ensuring to promote and encourage the expectations that ensure group work is fair.

I will also continue to give pupils a voice and a chance to share their ideas and opinions. When pupils have a say in the lessons they feel they have some sense of responsibility and control over their learning. This creates a sense of excitement among children, which increases their motivation. I will also try to plan lessons that are engaging and enjoyable and I will offer pupils choice and allow them to make decisions for themselves, as these too increase pupils' motivation.

Another recommendation I will continue to implement is to promote support among peers and to develop a classroom that is supportive of everyone's learning. French Walker and Shore (2011) discuss how to meet the needs of a child in terms of feeling supported in their learning. They suggest that these needs can be met by developing communities of learners who support each other and by enabling students to take on

a range of classroom roles that would usually be seen as the role of the teacher. To do this, I will encourage the children to celebrate each other's successes. I will ask the children to give each other compliments and praise until such time that this becomes a natural process. Instead of providing the answers to the children, I will develop a community of learners who help each other by enabling the children to become peer tutors, whereby they help each other if one child is having difficulty understanding a concept. Together, we can piece together information until the child arrives at an understanding.

In my practice going forward, I will implement flexible rather than homogenous groupings. Walker, Shore and French discuss homogenous grouping as groups of children with similar ability levels and heterogeneous groups as groups that consist of children with a range of abilities. Walker, Shore and French (2011) discuss how high-achieving pupils benefitted more, in terms of academics, in homogenous groups but that the self-esteem of these pupils 'increased in heterogeneous groups, but decreased in homogeneous groups' (Walker, Shore and French, 2011: 126). Therefore, the implementation of flexible grouping is important when using group work in the classroom.

Lastly, another factor which Walker et al. (2011), discuss as being an important contribution in a higher ability pupil's perception of group work is the pupil's ability to choose the pace at which they complete tasks and activities. They also suggest that in order 'to facilitate the success of all pupils within cooperative learning situations, tasks need to be flexible, challenging, and include several levels of difficulty and choice' (Walker, Shore and French, 2011: 124). Thus, I will implement these suggestions in my mathematics lessons from now on.

This is what I endeavour to do as I move forward with the process of action research in my future teaching practice. Going forward, I will be conscious of the changes and adjustments I have discussed and will implement these changes as I strive to continually improve my practice. However, I would also recommend that other teachers implement these suggestions in their teaching, should they wish to enhance their practice.

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Appendices

Appendix A

Ethics Approval for Master of Education (Research in Practice)

(*Please read the notes in this handbook before completing this form)*

Student name:	
Student Number:	
Supervisor:	
Programme:	
Thesis title:	
Research Question(s):	
Intended start date of data collection:	
Professional Ethical Codes or Guidelines used:	

1(a) Research Participants: Who will be involved in this research? *(Tick all that apply)*

Early years / pre-school	
Primary school students	
Secondary school students	
Young people (aged 16 – 18 years)	
Adults	

Provide a brief description of the individuals and their proposed role in your research below:

1(b) Recruitment and Participation/sampling approach: *How will these participants become involved in your research? What type of sampling is involved? Please describe the formal and informal recruitment processes? Please describe the type of participation and level of engagement of participants? Are there gatekeepers and what is their part of sampling process?*

2. Summary of Planned Research (*please indicate anonymised location type, purpose and aims of research, research questions and design, methods to be used and time frame, process of analysis) [250 words]*

3. Ethical Issues: Please outline the main ethical issues which may arise in the course of undertaking this research. *Outline the nature of consent and assent pertaining to participants. (You should discuss these concerns and outline the responses/supports you will provide in the boxes below)*

Power dynamics *(between researcher-participants, amongst participants, insider-research, reflexivity, gatekeepers, working with your colleagues, working with students, etc)*:

Informed consent and assent *(for participants - and guardians where appropriate. Please also note* any *other approvals that may be required from other bodies (i.e. Board of Management.):*

Sensitivity *(topics that may be potentially sensitive, intrusive or stressful, have you considered what to do in relation to dealing with the aftermath of a sensitive disclosure? how do you intend to deal with unexpected outcomes?)*

Data storage *(where will the findings be stored; will they be published? And by whom?)*

Attachments

Please attach, where available and applicable, information letters, consent forms and other materials that will be used to inform potential participants about this research.

Declaration *(Please sign and date)*

'I confirm that to the best of my knowledge this is a full description of the ethical issues that may arise in the course of undertaking this research.' If any of the conditions of this proposed research change, I confirm that I will re-negotiate ethical clearance with my supervisor.

Signed: _____ Date: _____

Supervisor use only:

Date Considered: _____

Approved	☐
Approved with recommendations (see below)	☐
Referred back to applicant	☐
Referred to Department Research and Ethics Committee	☐

Recommendations:

Signature of supervisor: _____

Department use only: *(only where applicable)*

Date Considered: _____

Approved by Froebel department Research and Ethics committee	☐
Approved with recommendations (see below)	☐
Referred back to applicant (changes to be approved by supervisor)	☐
Referred to Maynooth University Social Research Ethics Subcommittee	☐

Recommendations:

Signature of Dept. Ethics Committee Chair: _____

Maynooth University Social Research Ethics Subcommittee use only *(only where applicable)*

Date Considered: _____

Approved	☐
Referred back to applicant and supervisor	☐

Signed: _____
FSS Research Ethics Committee nominee

Checklist for students

Please complete the checklist below to confirm you have considered all ethical aspects of your research. **(Note that the consent form/s, assent form/s and information sheet/s that must accompany this application will be scrutinised and any omission or inadequacy in detail will result in a request for amendments).**	**Please tick**
I have attached (an) appropriate consent form/s, assent form/s and/or information sheet/s	
Each form and sheet is presented to a high standard, as befitting work carried out under the auspices of Maynooth University	
Each consent form has full contact details to enable prospective participants to make follow-up inquiries	
Each consent form has full details, in plain non-technical language, of the purpose of the research and the proposed role of the person being invited to participate	
Each consent form has full details of the purposes to which the data (in all their forms: text, oral, video, imagery etc.) will be put, including for research dissemination purposes	
Each consent form explains how the privacy of the participants and their data will be protected, including the storage and ultimate destruction of the data as appropriate	
Each consent form gives assurances that the data collection (questionnaires, interviews, tests etc.) will be carried out in a sensitive and non-stressful manner, and that the participant has the right to cease participation at any time and without the need to provide a reason	
Please include here any other comments you wish to make about the consent form(s) and/or information sheet/s.	

Appendix B

Maynooth University Froebel Department of Primary and Early Childhood Education

Roinn Froebel Don Bhun- agus Luath-Oideachas
Ollscoil Mhá Nuad.

06/11/2019

Dear Members of the Board of Management,

I am a student on the Master of Education programme at Maynooth University. As part of my degree I am doing an action research project. The focus of my research is based on my teaching of mathematics and how I can improve this using different teaching methodologies to make learning maths easier for the children.

In order to do this, I intend to carry out research in the classroom by using different teaching methodologies. I plan to use a combination of direct teaching and station teaching to teach the children the various maths topics. Direct teaching is the use of straightforward, explicit teaching techniques. It is a teacher-directed method. Station teaching involves me setting up different stations including an ICT station, games station, problem solving station, hands-on activity station etc.

The data will be collected using observations, conferences, voice recordings, transcripts, surveys and my personal reflective journal The children will be asked for their permission to participate in the research and I will respect their opinions throughout the research.

The children's names and the name of the school will not be included in the thesis that I will write at the end of the research. Parents/guardians will be asked for consent to allow their child to participate in the research process and parents/guardians will be able to withdraw their consent for their child's participation at any stage. Children will also be asked for their consent to participate in this research and they too will be allowed to withdraw from the research process at any stage should they wish to do so.

All information will be confidential and information will be destroyed in a stated timeframe in accordance with the University guidelines. Data collected will be adequate, relevant and not excessive. Data will be stored securely, using measure such as secure computer networks; ensuring that data is stored on secure premises; the use of password protection and data encryption; avoiding portable data storage devices such as laptops and USB sticks. The college guidelines will be complied with when carrying out this research. The research will not be carried out until approval is granted by the Froebel Department of Primary and Early Childhood Education.

I would like to invite you to give me permission to conduct this research in the school..

If you have any queries on any part of this research project feel free to contact me by email at Clare.kealy.2020@mumail.ie or by phone on the school's telephone number 0596473179.

Yours faithfully,

_____

CLARE KEALY

Maynooth University Froebel Department of Primary and Early Childhood Education

Roinn Froebel Don Bhun- agus Luath- Oideachas Ollscoil Mhá Nuad

06/11/2019

BOARD OF MANAGEMENT CONSENT FORM

We, the Board of Management, have read the information provided in the attached letter and are happy that all our questions have been answered. We agree to allow the student, Clare Kealy, to conduct her research in our school.

Chairperson's Signature_____

(On behalf of all Board members)

Date: _____

Appendix C

Maynooth University Froebel Department of Primary and Early Childhood Education

Roinn Froebel Don Bhun- agus Luath-Oideachas
Ollscoil Mhá Nuad.

Dear Parent(s)/Guardian(s),

I am a student on the Master of Education programme at Maynooth University. As part of my degree I am doing a research project. The focus of my research is based on my teaching of mathematics and how I can improve this using different teaching methodologies to make learning maths easier for the children.

In order to do this, I intend to carry out research in the classroom by using different teaching methodologies. I plan to use a combination of direct teaching and station teaching to teach the children the various maths topics. Direct teaching is the use of straightforward, explicit teaching techniques. It is a teacher-directed method. Station teaching involves me setting up different stations including an ICT station, games station, problem solving station, hands-on activity station etc.

The data will be collected using observations, conferences, voice recordings, transcripts, surveys and my personal reflective journal The children will be asked for their permission to participate in the research and I will value their opinions throughout the research.

The child's name and the name of the school will not be included in the thesis that I will write at the end of the research. Your child will be allowed withdraw from the research process at any stage.

All information will be confidential and information will be destroyed in a stated timeframe in accordance with the University guidelines. Data collected will be adequate, relevant and not excessive. Data will be stored securely, using measure such as secure computer networks; ensuring that data is stored on secure premises; the use of password protection and data encryption; avoiding portable data storage devices such as laptops and USB sticks etc. The correct guidelines will be complied with when carrying out this research. The research will not be carried out until approval is granted by the Froebel Department of Primary and Early Childhood Education.

I would like to invite you and your child to give permission for him/her to take part in this project.

If you have any queries on any part of this research project feel free to contact me by email at Clare.kealy.2020@mumail.ie or by phone on the school's telephone number 0596473179.

Yours faithfully,

_____

CLARE KEALY

Maynooth University Froebel Department of Primary and Early Childhood Education

Roinn Froebel Don Bhun- agus Luath-Oideachas
Ollscoil Mhá Nuad.

Information Sheet

Parents and Guardians

Who is this information sheet for?

This information sheet is for parents and guardians.

What is this Action Research Project about?

Teachers in the Research Masters in the Froebel Department of Primary and Early Childhood, Maynooth University are required to conduct an action research project, examining an area of their own practice as a teacher. Therefore, this project will involve an analysis of my own practice. Data will be collected and I am then required to produce a thesis documenting this action research project.

What is the research question?

- How can I enhance my practice of teaching maths using a combination of direct teaching and station teaching?

What sorts of methods will be used?

- Data will be collected using observations, conferences, voice recordings, transcripts, surveys and my personal reflective journal

Who else will be involved?

The study will be carried out by me as part of the Master of Education course in the Froebel Department of Primary and Early Childhood Education. The thesis will be submitted for assessment to the module leader Dr Bernadette Wrynn and will be examined by the Department staff. The external examiners will also access the final thesis.

What are you being asked to do?

You are being asked for your consent to permit me to undertake this study with my class. In all cases the data that is collected will be treated with the utmost confidentiality and the analysis will be reported anonymously. The data captured will only be used for the purpose of the research as part of the Master of Education in the Froebel Department, Maynooth University and will be destroyed in accordance with University guidelines.

Contact Details:

If you have any queries on any part of this research project feel free to contact me by email at Clare.kealy.2020@mumail.ie or by phone on the school's telephone number 0596473179.

Maynooth University Froebel Department of Primary and Early Childhood Education

Roinn Froebel Don Bhun- agus Luath-Oideachas
Ollscoil Mhá Nuad

PARENTAL CONSENT FORM

I have read the information provided in the attached letter and all of my questions have been answered. I voluntarily agree to the participation of my child in this study. I am aware that I will receive a copy of this consent form for my information.

Parent / Guardian Signature_____

Parent / Guardian Signature_____

Date: _____

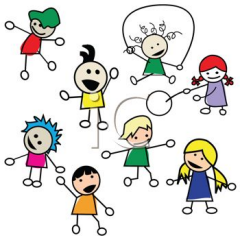
Name of Child _____

Child's signature: _____

Date: _____

Maynooth University Froebel Department of Primary and Early Childhood Education

Roinn Froebel Don Bhun- agus Luath- Oideachas Ollscoil Mhá Nuad



Child's name …….

I am trying to improve my teaching to help you learn maths in an easier way. I would like to find out more about this. I would like to watch you and listen to you when you are in school and to write down some notes about you.

Would you be ok with that? Pick a box **Yes** **No**

I have asked your Mum or Dad or Guardian to talk to you about this. If you have any questions I would be happy to answer them. If you are happy with that could you sign the

form that I have sent home? If you change your mind after we start, that's ok too.

Maynooth University Froebel Department of Primary and Early Childhood Education

Roinn Froebel Don Bhun- agus Luath- Oideachas Ollscoil Mhá Nuad.

Child's assent to participate

My parent/guardian has read the information sheet with me and I agree to take part in this research.

Name of child (in block capitals):

_____

Signature: _____

Date: _____

Appendix E

Date: Lesson No:					Strand: Strand Unit:				
Behaviours	Pupils:								
	021	020	019	018	017	016	015	014	013
Talk related to task									
Answering questions									
Engaed in task/work									
Listening well									
Talk not task related									
Wandering around the room									
Attempting to distract others									
Day Dreaming/ Disengaged									

SYSTEMATIC OBSERVATION OF INDIVIDUAL PUPILS

SCHOOL:

CLASS:

DATE:

LESSON:

TEACHER:

SUBJECT:

OBSERVATION:

Observe the pupil every 5 minutes and record their behaviour at the time

	BEHAVIOURS	Tally Chart of Observed Behaviours for 5 Focus Pupils					
		Pupil 1	Pupil 2	Pupil 3	Pupil 4	Pupil 5	**Total**
ON TASK	Talk related to task						
	Answering question						
	At work						
	Listening to teacher/peer						
OFF TASK	Talk not task related						
	Wandering around room						
	Attempting to draw attention						
	Day dreaming						
	Total						

(Baumfield, Hall & Wall, 2013, p.76)

Appendix G

Learner-Centered Rubric for Classroom Observations (based on Weimer, 2013)

#1: The role of the teacher (The teacher is not a conveyor of information; the teacher is a facilitator. It's the students who do the hard messy work of learning; they are not passive recipients of knowledge.)

Learner-Centered	Transitional	Teacher-Centered	Comments
Description: For the majority of the class session, the teacher does not simply convey information; the teacher facilitates significant learning experiences in which the students engage in the authentic work of the discipline and learn the information for themselves.	*Description: There is a mix of lecture and student engagement.*	*Description: The teacher does the vast majority of talking, summarizing, and analyzing.*	
1. For the majority of the class session, the teacher acts as a resource person (giving constructive feedback, eliciting different approaches, encouraging repeated attempts, etc.), working to support and enhance student investigations.	1. Occasionally during the class session, the teacher acts as a resource person, working to support and enhance student investigations.	1. The teacher does not act as a resource person during class, working to support and enhance student investigations.	
2. The teacher expects students to generate examples, review material, solve problems, lead discussions, critically analyze information, etc.	2. There are opportunities for the students to generate examples, review material, solve problems, etc., but these opportunities are limited or the purpose of the activities is not clearly connected to course material.	2. The class session consists predominantly of the teacher conveying information; students watch while the teacher works.	
3. Questions are welcomed by the teacher, and the teacher makes an effort to redirect to the rest of the class so that other students answer questions rather than the teacher.	3. Questions are welcomed by the teacher, but questions are mostly answered by the teacher rather than other students.	3. Questions from students may be entertained to a limited degree.	
4. The teacher ensures that the tasks students do in class are challenging.	4. The teacher ensures that the tasks students do in class are moderately challenging.	4. The teacher doesn't provide any opportunities for students to engage in challenging tasks. Alternately, the tasks that are provided are not very challenging.	

#2: The balance of power (The students have some control of the learning process.)

Learner-Centered	Transitional	Teacher-Centered	Comments
Description: The students appear to have a great deal of control over the learning that occurs in the classroom.	*Description: The students appear to have some control over the class.*	*Description: The students appear to have no control over the class.*	
5. Student questions and comments often determine the focus and direction of learning/instruction.	5. Student questions and comments are encouraged and answered, but those questions/comments do not determine the focus and direction of the class or prompt the teacher to change the current focus.	5. Student questions and comments are rare.	
6. Students have control over what content will be learned.	6. Students appear to have some choices with regard to content, but not a great deal.	6. The teacher appears to control all aspects of the class session.	
7. There is a high proportion of student talk related to content, and a significant amount of it occurs between and among students.	7. There is a high proportion of student talk related to content but usually between teacher and student.	7. There is very little student talk related to content; the teacher does most or all of the talking.	

#3: The function of content (Instead of "covering" the material, the students develop learning skills and learn how to think like those in the discipline.)

Learner-Centered	Transitional	Teacher-Centered	Comments
Description: The teacher does not overwhelm the students with a large amount of content. Content functions as a vehicle for skill development.	*Description: There is some evidence of the teacher and students addressing learning skills and using content to help students think like professionals in the discipline.*	*Description: Content is covered by the teacher and is not used in a way that promotes students thinking like professionals in the discipline. Learning skills are not developed by the students.*	
8. There is evidence that the teacher helps students learn how to ask good questions, how to read effectively, how to critically analyze information, how to write, how to study, how to summarize information, how to work effectively in groups.	8. There is some evidence that the teacher helps students learn how to ask good questions, how to read effectively, how to critically analyze information, how to write, how to study, how to summarize information, how to work effectively in groups.	8. There is no evidence that the teacher helps students learn how to ask good questions, how to read effectively, how to critically analyze information, how to write, how to study, how to summarize information, how to work effectively in groups.	
9. The tasks that students do in class seem to reinforce skill development (e.g., students need to read effectively in order to solve problems or analyze case studies in class; they need to work effectively in groups in order to be successful in the class).	9. Some of the tasks that students do in class reinforce skill development (e.g., students need to read effectively in order to solve problems or analyze case studies in class; they need to work effectively in groups in order to be successful in the class).	9. The students do no tasks in class that reinforce skill development; the teacher is primarily covering content.	
10. Content is utilized in such a way to provide opportunities for students to think like professionals in the discipline.	10. Content is utilized in such a way to provide some opportunity for students to think like professionals in the discipline.	10. Content is not utilized in such a way as to help students think like professionals in the discipline.	

#4: Student responsibility for learning (The teacher's role is to be approachable, caring, consistent, and make sure the student experiences consequences when he/she fails to live up to the responsibility.)

Learner-Centered	Transitional	Teacher-Centered	Comments
Description: The classroom atmosphere is such that students are held responsible for their learning and take that responsibility willingly.	*Description: The teacher does a relatively good job of ensuring that students are responsible for learning and that there exists a warm classroom climate, but the efforts fall short in some ways.*	*Description: There is little to no evidence that students take responsibility for learning.*	
11. Students are expected to have prepared before class and there is evidence that the majority in fact have actually prepared (e.g., they are able to answer questions about the prior information, they can apply the prior information to new situations, they ask questions that show that they've prepared beforehand).	11. Although students are expected to have prepared before class, many have not and there are no consequences.	11. There is little to no evidence that students were supposed to prepare anything for the class session.	
12. The teacher is patient and caring, knows all or most students by name. The teacher listens carefully to students. The teacher treats students fairly and consistently (in other words, no one gets "special treatment," there is consistency between what the teacher says and what he/she does).	12. The teacher is mostly caring, but there may be a few issues, such as some students getting special treatment, not knowing several students' names, occasionally seeming to not listen carefully to students, showing minor impatience occasionally. Alternately, the teacher appears patient and caring, but he or she interacts so little with students that it is difficult to evaluate other dimensions like the extent to which the teacher listens carefully, knows all of the students' names, etc.	12. The teacher does not exhibit patience or a caring attitude. The teacher appears to know very few or no students' names except for possibly a "favorite" or two.	
13. All or almost all students put effort into the class (e.g., they arrive on time, they're not on their computers or cell phones during the class, they participate in class when asked). If some students choose not to put in effort, the teacher is aware and takes action to engage them.	13. The majority of students put effort into the class (e.g., they arrive on time, they're not on their computers or cell phones during the class, they participate in class). However, when they fail to put effort in, there are no consequences (the teacher seems to not notice or ignores the behavior).	13. The majority of students are not paying attention or putting effort into the class (e.g., many students are late, they're on computers, etc.). The teacher does not seem to notice/care.	
14. Expectations are high, and students appear to respond positively. The students support each other in achieving those high expectations.	14. Expectations are neither high nor low. OR, expectations are high and some students respond positively whereas others appear to be frustrated and struggling.	14. Expectations are low. OR, expectations are high and students respond negatively.	
15. There is a positive climate in the classroom (e.g., mutual respect, good rapport between the students and the teacher and among the students, students listen to each other and respond to each other respectfully).	15. There is an average climate in the classroom. For example, the students are polite, but they don't seem to listen or respond to each other. Alternately, there is little opportunity to judge the climate because there is little interaction in the class.	15. There is a negative climate in the classroom. For example, students may be openly hostile to each other or the teacher. Students pay attention to the teacher but tune out when other students talk. Students "clockwatch" in the classroom.	

#5: The learning potential in assessments (Evaluation is more than just getting a grade. It promotes learning. The teacher's job is to come up with ways to use evaluation to promote learning. Self-assessment and peer assessment should be promoted. The traditional kinds of assessment are restructured to promote learning.)

Learner-Centered	Transitional	Teacher-Centered	Comments
Description: The teacher uses assessments to promote learning in creative ways.	*Description: There is some effort to use assessments to promote learning but there are missed opportunities as well.*	*Description: The learning potential in assessment is ignored.*	
16. Students have opportunities for self-assessment/reflection (e.g., reflection minute papers, reflection about assignments, reflection connecting material in class to the students' personal lives, asking questions such as "How do you know you're correct?").	16. There is some opportunity for self-assessment/ reflection in the class.	16. There is no self-assessment or reflection.	
17. There is student peer assessment during the class (e.g., the teacher uses questions such as asking for one student to restate and comment on another student's answer, the students evaluate each others' work.).	17. There is some evidence of peer assessment during the class.	17. The teacher is the only one assessing work (for example, the teacher tells the students when they are correct or incorrect).	
18. The teacher uses various formative assessment techniques during class (e.g., ticket out the door, clickers, group work) and acts on those assessments to improve student learning and move the class forward.	18. The teacher uses some formative assessments (e.g., clickers, worksheets, asking questions, etc.), but it's not clear that these assessments improve student learning or move the class forward.	18. There is no use of formative assessments.	
19. The teacher emphasizes the importance of learning and understanding the material (not for points or grades).	19. The teacher puts some emphasis on the importance of learning and understanding the material, but also places some emphasis on grades (e.g., the teacher says things like, "You'll need this for the test," "You need this information to get points on the assignment").	19. The teacher and students are focused on grades (e.g., "Will this be on the test?", the teacher says things like, "You'll need this for the test," "You need this information to get points on the assignment").	

For each of the 19 categories, circle the description that best matches the observation. Add up each column and multiply the sum by 2 for learner-centered, 1 for transitional, and 0 for teacher-centered. Then add up the total score.

Score	Type of Class
0-13	Teacher-centered
14-25	Transitional
26-38	Learner-centered

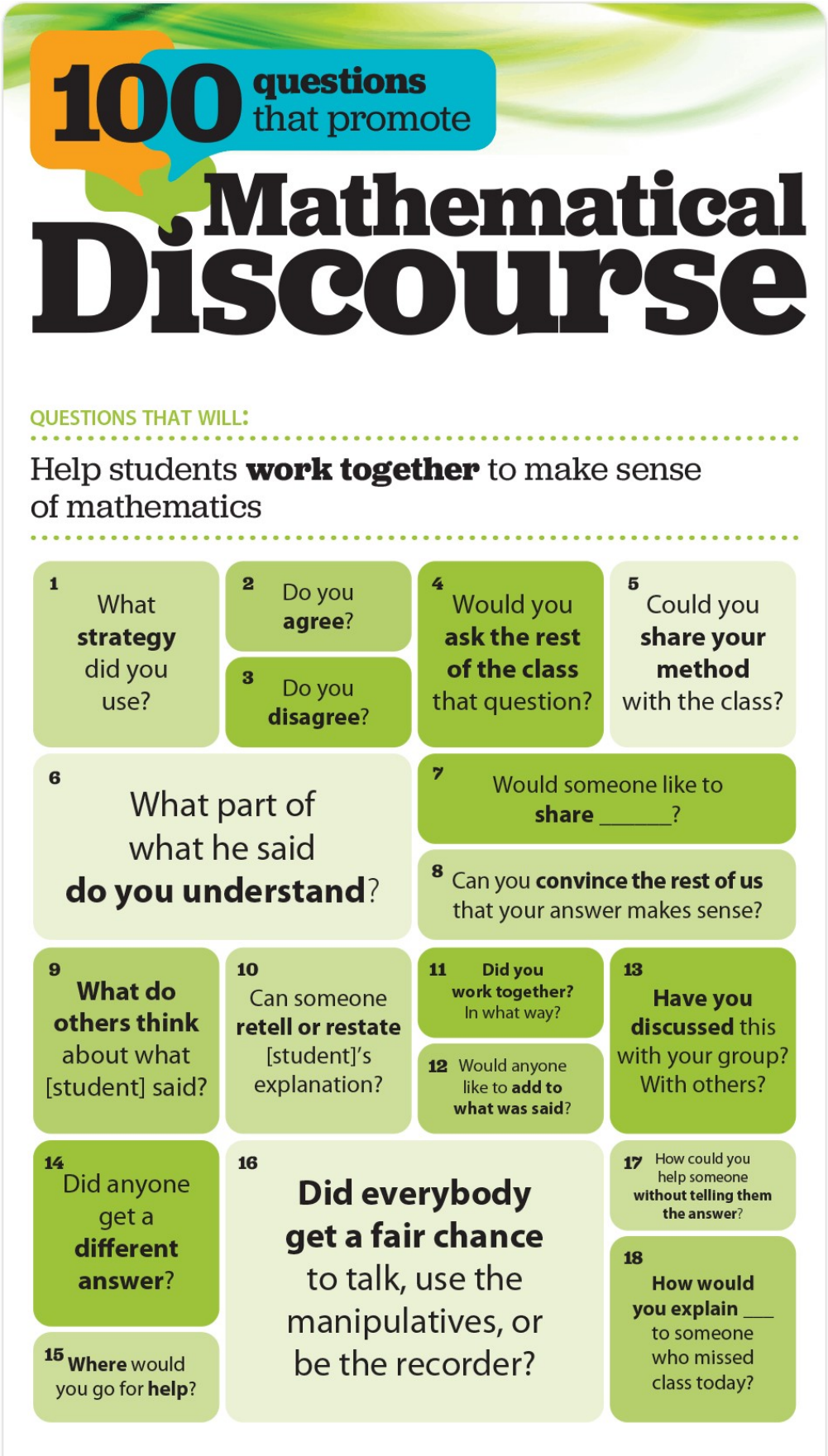
Appendix H

Risk Management Procedures:

The following management procedures will be implemented to manage the risk of harm to participants:

- I will orally outline the purpose of the research to the child so that they can, with the guidance of their parents, give their consent to be involved.
- I will do my best to ensure that nothing I do or say will result in negative consequences for the child.
- I will do my best to always ensure that the child's self-esteem is protected. In order to minimise the risk of affecting a child's self-esteem I will make sure not to ask questions of a difficult or sensitive nature. I will ask questions in privacy if there is an issue.
- Participants will not be exposed to risks beyond what might reasonably be encountered in daily life.
- Where possible I will try to recognise any potential risks in advance of data collection and thus be prepared for and be able to minimise and manage any distress or discomfort that may arise.
- If unforeseen consequences/ unanticipated outcomes arise, it may be appropriate to go back to the participants or gatekeepers in order to renegotiate consent.
- I will make known to the participants (or their guardians or responsible others) any predictable disadvantage or harm potentially arising from the process or reporting of the research.
- Out of professionalism I will inform other staff members about the research, eventually sharing the findings to improve mathematics teaching in the school as a whole.

Appendix I


100 questions that promote
Mathematical Discourse
QUESTIONS THAT WILL:
Help students work together to make sense of mathematics
1 What strategy did you use?
2 Do you agree?
3 Do you disagree?
4 Would you ask the rest of the class that question?
5 Could you share your method with the class?
6 What part of what he said do you understand?
7 Would someone like to share _____?
8 Can you convince the rest of us that your answer makes sense?
9 What do others think about what [student] said?
10 Can someone retell or restate [student]'s explanation?
11 Did you work together? In what way?
12 Would anyone like to add to what was said?
13 Have you discussed this with your group? With others?
14 Did anyone get a different answer?
15 Where would you go for help?
16 Did everybody get a fair chance to talk, use the manipulatives, or be the recorder?
17 How could you help someone without telling them the answer?
18 How would you explain ___ to someone who missed class today?

QUESTIONS THAT WILL:

Help students with **problem comprehension**

39 What is this problem about? What can you **tell me about it**?

40 Do you need to **define or set limits for** the problem?

41 How would you **interpret** that?

42 Could you **reword that in simpler terms**?

43 Is there something that can be **eliminated** or that is **missing**?

44 Could you **explain** what the problem is asking?

45 What **assumptions** do you have to make?

46 What do you **know** about this part?

47 **Which words were most important**? Why?

QUESTIONS THAT WILL:

Help students learn to **conjecture, invent, and solve problems**

48 **What would happen if ___?**

49 Do you see a **pattern**?

50 What are some **possibilities** here?

51 Where could you find the **information** you need?

52 How would you **check your steps** or your answer?

53 What **did not work**?

54 How is your solution method the **same as or different from** [student]'s method?

55 Other than retracing your steps, **how can you determine** if your answers are appropriate?

56 How did you **organize** the information? Do you have a **record**?

57 How could you solve this using **tables, lists, pictures, diagrams**, etc.?

58 What have you tried? What **steps** did you take?

59 How would it look if you used this **model** or these **materials**?

60 How would you draw a **diagram or make a sketch** to solve the problem?

61 Is there **another possible answer**? If so, explain.

62 Is there **another way** to solve the problem?

63 Is there **another model** you could use to solve the problem?

64 Is there anything you've **overlooked**?

65 **How did you think** about the problem?

66 What was your **estimate or prediction**?

67 How **confident** are you in your answer?

68 **What else** would you like to know?

69 What do you think comes **next**?

70 Is the solution **reasonable**, considering the context?

71 Did you have a **system**? Explain it.

72 Did you have a **strategy**? Explain it.

73 Did you have a **design**? Explain it.

QUESTIONS THAT WILL:

Help students learn to **connect mathematics, its ideas, and its application**

74 What is the **relationship** between ___ and ___?

75 Have we ever solved a problem **like this before**?

76 What uses of mathematics did you find in the **newspaper** last night?

77 What is the **same**?

78 What is **different**?

79 Did you use skills or build on concepts that were **not necessarily mathematical**?

80 Which **skills or concepts** did you use?

81 What **ideas** have we explored before that were useful in solving this problem?

82 Is there a **pattern**?

83 **Where else** would this strategy be useful?

84 How does this **relate** to ___?

85 Is there a **general rule**?

86 Is there a **real-life situation** where this could be used?

87 How would your method work with **other problems**?

88 What other problem does this seem to **lead to**?

QUESTIONS THAT WILL:

Help students **persevere**

89 Have you tried making a **guess**?

90 **What else** have you tried?

91 Would **another method** work as well or better?

92 Is there **another way** to draw, explain, or say that?

93 Give me another **related problem**. Is there an easier problem?

94 How would you **explain** what you know right now?

QUESTIONS THAT WILL:

Help students focus on the mathematics from **activities**

95 What was **one thing you learned** (or two, or more)?

96 Did you **notice any patterns**? If so, describe them.

97 What **mathematics topics** were used in this investigation?

98 What were the **mathematical ideas** in this problem?

99 What is mathematically **different about these two situations**?

100 What are the **variables** in this problem? What stays **constant**?